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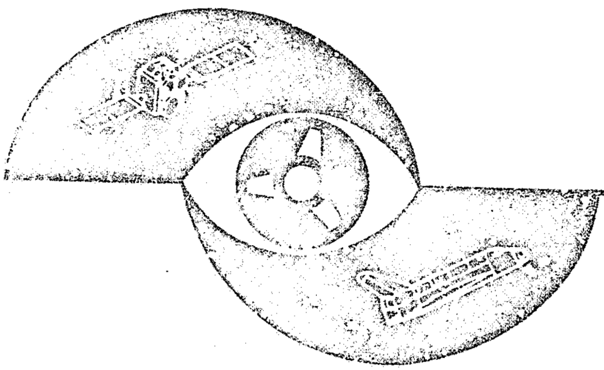

SPACE SYSTEMS DIVISION

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LANDSAT-D

FLIGHT SEGMENT

OPERATIONS MANUAL

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REVISION LOG

This log identifies those portions of this specification which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Paragraph Number(s) Affected	Rev. Date

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14.0 THEMATIC MAPPER

SECTION 14.0

THEMATIC MAPPER (TM)

The Thematic Mapper (TM) is a seven-band multispectral high resolution scanner capable of fulfilling the observational requirements for improved land use, water resources and food supply/distribution management. The instrument consists of a scanning mechanism, primary imaging optics, spectral band discrimination optics, detectors, radiative cooler, in-flight calibrator and operating/processing electronics. It will collect, filter and detect radiation from Earth in a swath 185 km wide. The scanning mechanism provides the cross-track scan (swath width) while orbital motion provides scan along the track. The variation in radiant flux passing through the field stop onto the detectors creates an electrical output which represents the radiant history of the line. The TM will quantize and mult[illegible] signals from all its data channels (detectors) into serial digital data for subsequent RF transmission by the Wideband Communications Subsystem.

14.1 TM FUNCTIONAL DESCRIPTION

The overall configuration of the Thematic Mapper is shown in Figure 14.1-1. A functional illustration is presented in the abbreviated block diagram of Figure 14.1-2.

Radiant energy enters the instrument through the aperature which is protected by the sun shade. Scanning of the field is done by the scan mirror in the crosstrack direction and by the motion of the flight segment in the along-track direction. The scan mirror is a 16x21-inch ellipse which presents equal area at all scan angles. It provides a linear scan motion covering a swath on the ground 185 Km wide. The Scan Mirror Electronics (SME), a precision digital driver, drives the mirror. A scan line corrector (SLC) located behind the primary optics compensates for the forward motion of the spacecraft and allows the scan mirror to provide usable data in both scan directions.

The telescope is of Ritchey-Chretien type. It contains an internal calibration system for both the visible and thermal bands. It has a ground-commandable focus adjustment and a registration alignment mechanism for the infra-red bands.

The detector package for the visible and near infrared (IR) bands (1,2,3 and 4) consists of 4 linear arrays of 16 silicon detectors each located at the uncooled focal plane. The middle IR bands (5 and 7) consists of 16 indium-antimonide photo diodes each. The far IR Band (6) consists of 4 mercury-cadmium-telluride detectors. The sensors for bands 5, 6 and 7 are located on a radiative cooler at the cooled focal plane. The positions of the uncooled and cooled sensor packages in the optical system is shown in Figure 14.1-3.

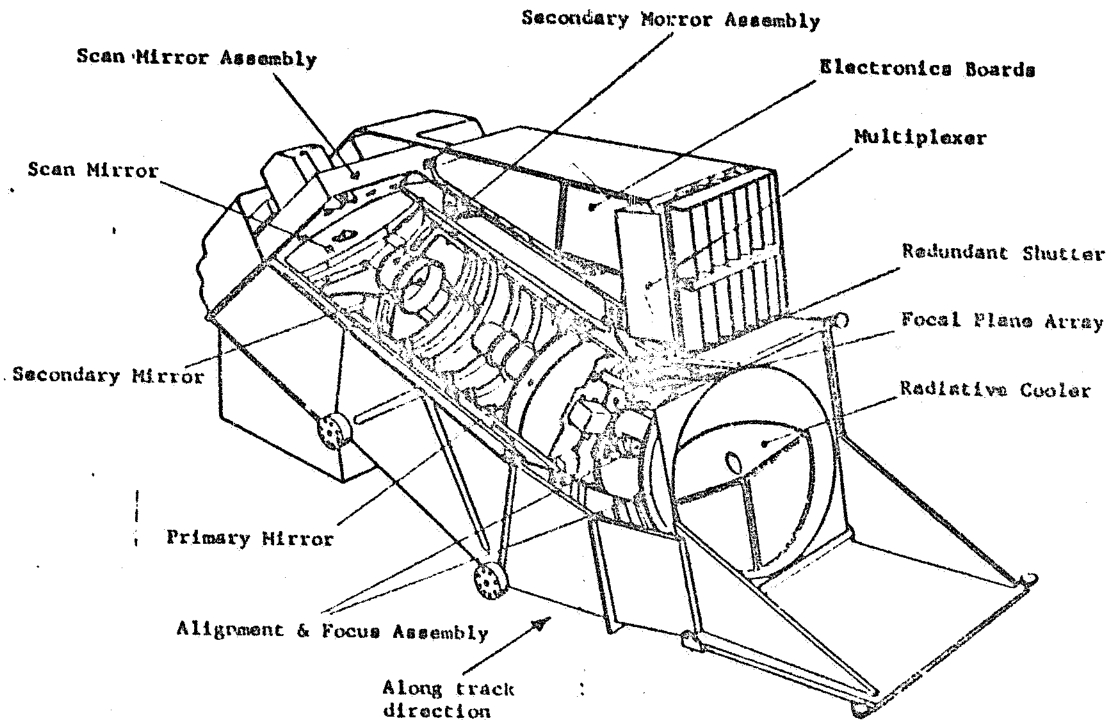

Figure 14.1-1. Thematic Mapper General Configuration

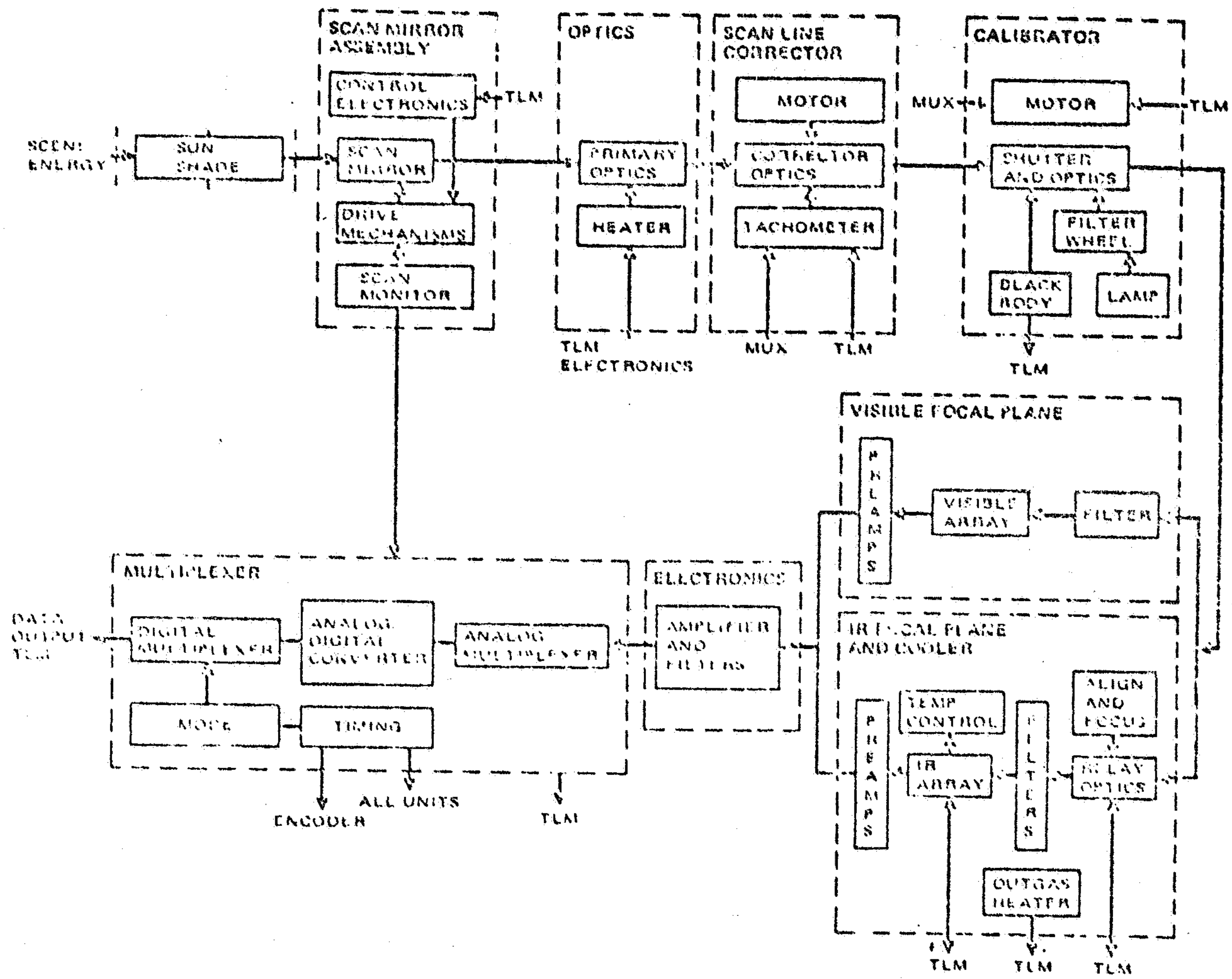

Figure 14.1-2. Thematic Mapper Functional Block Diagram

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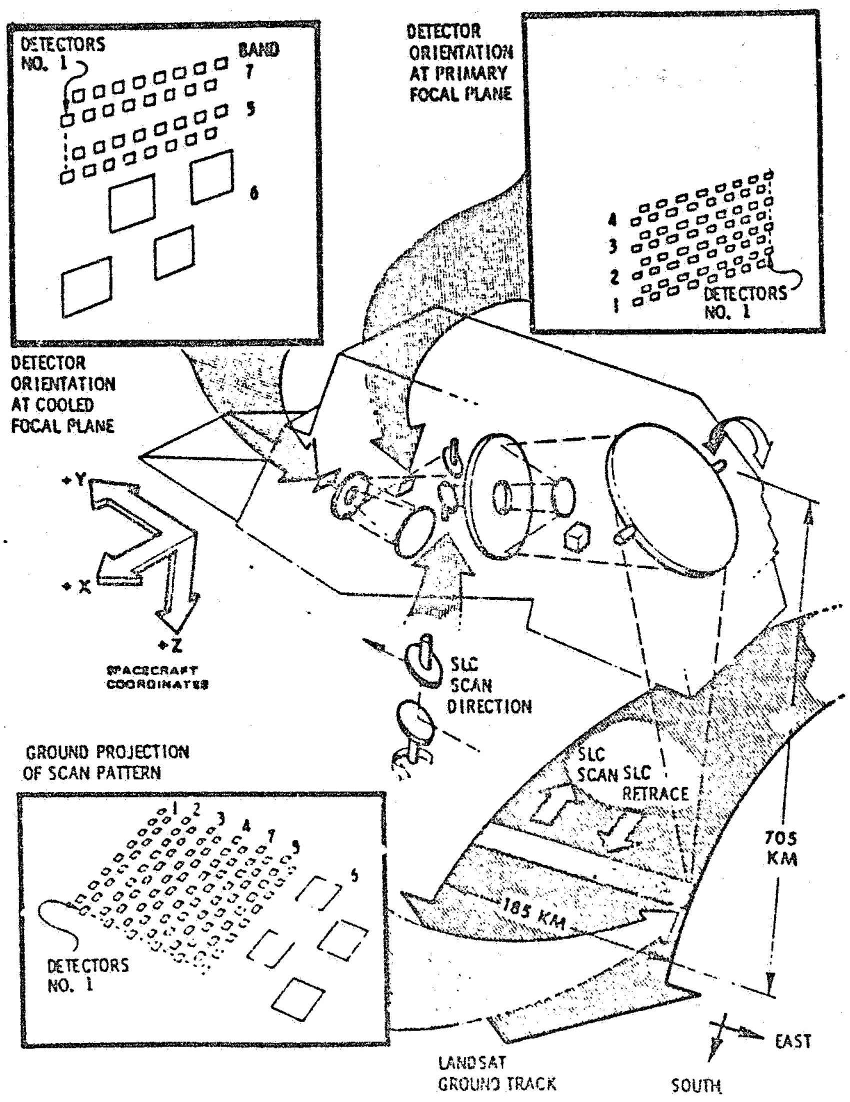

Figure 14.1-3. Thematic Mapper Optical System and Sensor Location

Internal calibration and D.C. restore, for both visible and thermal bands, are introduced during scan mirror turn-around near the prime focal plane by the primary oscillating calibration/restore shutter assembly. This shutter assembly operates at the same frequency as the scan mirror. The internal calibrator employs three minature tungsten lamps, optical filters and fiber optics to produce eight radiance levels within the dynamic range of each of Bands 1 to 5 and 7. A blackbody located adjacent to the prime focal plane is used to obtain three temperature levels in Band 6. The blackbody image is projected into the Band 6 field of view by a mirror located on the calibration/restore shutter. In the event of primary shutter failure, a mechanism actuated by a fusible link will retract the primary shutter and permit usage of the backup shutter mechanism. The backup shutter provides DC restore only. The radiative cooler is a multi-stage unit that provides a 95°K environment for the detectors of Bands 5, 6 and 7. The radiation cooler door used for launch and recovery cleanliness--as well as an earth albedo shield--has three commandable positions: 1) door open, 2) door closed, 3) door outgas. The door motor has an integral brake which is disengaged when power is applied to the motor and stops the motor rotation when power is removed. In the event of door motor failure, a fusible, spring-loaded link assembly is actuated, allowing the opening of the radiation cooler door.

A ground commandable focus adjustment and registration alignment is provided for on-orbit adjustment of the infrared bands. This is accomplished with piezo-electric actuator (inchworm) assemblies. These devices support the spherical mirror mount and will provide linear movement as a result of the property of piezo-ceramic material that causes a dimensional change when an electrical charge is induced. The successive clamping and unclamping of collars around the piezoceramic rods and application of voltage to the piezoceramic rod material causes the mirror to move providing mirror focus and adjustment.

The signals from the detectors are amplified, filtered and sent to the TM multiplexer. The multiplexer accepts the data, analog multiplexes all detector channels in each band on a single channel, converts to digital, and multiplexes the digital channels along with sync, timecode, mirror position information and telemetry into a signal acceptable to the wideband communications subsystem. This data is formated into a 84.9 Mbps data stream. This format is described in the Data Format Control Book, Volume V (Payload).

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14.2 TM PERFORMANCE CAPABILITIES

THEMATIC MAPPER PARAMETER LIST

General Parameters	
Weight (Max)	243 kg
Power	
o Max	365 w
o Normal, bands 1-7	282 w
Resolution	30 m
Data Rate	84.9 Mbps
Scan Mirror Parameters	
Swath width	185 km
Active scan angle	0.1343 rad
Swath width at 0o N	480 m
Data rate	84.903 Mbps
Scan frequency	6.9967 Hz
Scan period	142.925 ms
Scan rate	4.421910 rad/sec
Scan efficiency	85%
Active scan time	60.743 ms
Turnaround time	10.719 ms
IFOV dwell time	9.611 usec
Scan line length	6320 IFOV
Inertia	0.37 in-lbf-sec^2
Clear aperture	41.05 by 53.24 cm (ellipse)
Reflectance	
Band 1	0.95
Band 2 to 5, 7	0.97
Band 6	0.94
Primary Telescope Parameters	
Primary diameter	40.6 cm
Primary area	1297.2 cm^2
Secondary obscuration diameter	15.8 cm
Secondary obscuration area	194.8 cm^2
Effective focal length	243.8 cm
f/no.	6.0
Primary/Secondary reflectance	
Band 1	0.94
Band 2	0.95
Band 3, 4	0.97
Band 3, 4	TBD
Scan Line Corrector	
Scan frequency	13.99 Hz
Scan period	71.462 ms

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Scan efficiency	85.3%
Active scan time	61.0 ms
Turnaround time	10.46 ms
Scan Rate in object space	9.61 mr/sec
Rotation rate	576.6 mr/sec
Rotation amplitude	35. mr
Mirror separation	4.064 cm
Linear image displacement amplitude	0.1420 cm
Linear image displacement rate	2.332 cm/sec
Mirror reflectance	
Band 1 to 4, 6	0.95
Band 5, 7	0.96

<u>Cold Focal Plane Assembly</u>

Detector size	
Bands 5, 7	0.00533 cm^2
Band 6	0.0207 cm^2
Detector sensitive area	
Bands 5, 7	2.84 by 10^{-5} cm^2
Band 6	4.29 by 10^{-4} cm^2
Number of detectors	
Bands 5, 7	16 each band
Band 6	4
Center-to-center spacing in each row	
Bands 5, 7	0.01035 cm
Band 6	0.0414 cm
Center-to-center spacing between rows	
Bands 5, 7	0.01295 cm
Band 6	0.0518 cm
IFOV size	
Bands 5, 7	43.75 urad
Band 6	170.0 urad
Detector operating temperatures	90^o, 95^o, 100^oK

<u>Prime Focal Plane Assembly</u>

Detector size	0.01036 cm^2
Detector sensitive area	107.4 by 10^{-6} cm^2
Center-to-center spacing in each row	0.0207 cm
Center-to-center spacing between rows	0.0259 cm
IFOV size	42.5 urad
Number of detectors	
Bands 1 to 4	16 each band
Signal bandwidth	52.02 kHz
Detector operating temperature	10^o to 25^oC

<u>Relay Optics</u>

Folding mirror diameter	8.06 cm
Clear aperture diameter	7.44 cm

Second mirror diameter	14.22 cm
Clear aperture diameter	13.57 cm
Magnification	0.5
f/no.	3.0
Mirror reflectance	
Bands 5, 6, 7	0.98
Ambient dewar window transmission	0.93 (bands 5, 6, 7)
Spectral Bandwidths, um	
Band 1	0.45 to 0.52
Band 2	0.52 to 0.60
Band 3	0.63 to 0.69
Band 4	0.76 to 0.90
Band 5	1.55 to 1.75
Band 6	10.4 to 12.5
Band 7	2.08 to 2.35
Radiative Cooler Parameters	
Horizontal field of view	160°
Vertical field of view	114°
Intermediate stage radiator area	690 cm^2
Cold stage radiator area	430 cm^2
Radiation surface characteristics	Black painted honeycomb
Cold stage temperature capability	
3 cooled bands	81.6°K
Cold stage control temperatures	90.0°, 95.0°, 105.0°K

14.3 TM MODES OF OPERATION

The TM operates in any of three configurations. Six normal operational modes have been defined. The configurations and modes are discussed in the following paragraphs.

14.3.1 TM CONFIGURATIONS

There are three TM configurations: Primary, Redundant, and Mixed. In the primary configuration, all TM components designated 1 or prime have been selected. In the redundant configuration, all TM components designated 2 or redundant have been selected. Any configuration containing mixtures of "1" and "2" or "Prime" and "Redundant" components is a mixed configuration. The command sequences used to obtain the Primary and Redundant configurations are defined in Paragraph 14.6.2.

14.3.2 TM OPERATIONAL MODES

A large number of TM modes are feasible. A number of standard modes are defined in this paragraph. Modal definitions are independent of configuration. The standard TM modes are Launch, Off, Standby, and Image.

14.3.2.1 TM Launch Mode

In launch mode the TM is configured as if it were in IMAGE mode except: power supplies are off, TM buses A and B are disabled, fuselink power is disabled, 19 volt standby power is off, safehold and standby heaters are enabled, SMA heater power is enabled, the radiative cooler door is closed and magnetic door latches are on. Launch mode power is approximately 12 watts. The command sequence to be used to obtain the launch mode appears in Paragraph 14.6.2.

14.3.2.2 TM Off Mode

In the off mode the TM is configured as if it were in IMAGE mode except: power supplies are off, TM power buses A and B are enabled, the SMA heater bus is enabled, the fuse link bus is enabled, the safehold and standby heaters are enabled, and the +19 volt standby power is off. The command sequence required to place the TM in the off mode appears in Paragraph 14.6.2.

14.3.2.3 TM Standby Mode

The TM standby mode maintains the TM, thermally, so that it will produce in-specification images within four minutes of turn on. In the standby mode, the following components are temperature controlled: scan mirror assembly, baffles, calibration blackbody, and the cold focal plane assembly. In standby, the TM is configured as if it were in IMAGE mode except: the power supplies are off and +19 volt standby power is on. The command sequence used to obtain standby mode is defined in Paragraph 14.6.2.

14.3.2.4 TM Image Mode

The TM image mode provides data to the wideband communications subsystem representative of the multispectral scene "viewed" by the TM. In the image mode the TM configuration is as follows: power supply on, mux on, bands one through 7 on, scan mirror on in SAM control mode, thermal shutdown enabled, calibration lamps 1, 2 and 3 on, calibration sequencer on, calibration shutter on in amplitude and phase lock, CFPA controller on with set point T_1 selected, blackbody controller on with T_1 selected, door electromagnets off, MDCG's on, DC restore normal, telemetry scaling on, inchworms off, LVDT on, cooler door open, midscan off, SMA heaters enabled, cooler telemetry enabled fuselinks safe, scan line corrector on and baffle heaters enabled. The image mode command sequence is defined in Paragraph 14.6.2.

14.3.2.5 Earth Pointing Safehold Mode

In the earth pointing safehold mode the TM should be configured as follows: TM power A and B disabled TM SMA heater bus enabled, TM safehold heater power and thermostats enabled and external standby heaters enabled. The TM +19 volt external standby power should be turned on as soon as command capability is established.

14.3.2.6 Inertial Safehold Mode

In the inertial safehold mode, the TM power buses shall be configured as in the earth pointing safehold and the cooler door shall be closed as soon as command capability is established (see Paragraph 14.6.2.26).

14.4 THEMATIC MAPPER CONSTRAINTS

14.4.1 TM TELEMETRY CONSTRAINTS

Thematic mapper passive analog telemetry is always valid. Analog and serial digital telemetry require that the TM be on and in the appropriate mode. Telemetry validity is addressed on an individual telemetry function basis in Paragraph 14.7.

14.4.2 TM COMMAND CONSTAINTS

14.4.2.1 Discrete to Serial Magnitude Command Timing

A discrete command shall not be directed to the TM within 32 milliseconds of a serial command message associated with serial magnitude command 871 or 872.

14.4.2.2 Serial Command Message Timing

Serial command messages associated with a unique TM serial command (871 or 872) shall be separated by a minimum of 10 seconds.

14.4.2.3 Serial Command Message Content.

Serial command messages associated with commands 871 and 872 shall contain no more than one (1), one (1).

14.4.2.4 Multiplexer Operation

The multiplexer shall not be commanded on if inchworm power is on.

14.4.2.5 Multiplexer Turn-On

The multiplexer turn-on commands (MUX1ON or MUX2ON) shall not be executed within 20 milliseconds of issuing a power supply on command (PS1ON or PS2ON), one (1).

14.4.2.6 Inchworm Operation

The inchworm power supply shall not be turned-on (IWON) if the multiplexer is on.

14.4.2.7 Calibration Shutter

Once the calibration shutter is powered off, power shall not be resupplied for at least 60 seconds to allow the slow start capacitor to discharge.

14.4.3 TEMPERATURE CONSTRAINTS

14.4.3.1 Scan Mirror Assembly

The scan mirror shall not be turned-on if the scan mirror assembly temperature, as monitored by +Z or -Z SMA housing temperture monitors (TDWNSMT or TUPSMT), is less than $10^{o}C$.

14.4.3.2 Power Supply Temperature

If the power supply temperature (TPST) exceeds 30^{o} centigrade, the power supply shall be turned off. If the power supply temperture is less than $10^{o}C$ the external standby power shall be enabled.

14.4.3.3 Multiplexer Temperature

If the multiplexer temperature (TMUXET) exceeds $50^{o}C$, the mux shall be turned off.

14.4.3.4 SLC Temperature

If the scan line corrector temperature (TSLCT) exceeds $40^{o}C$ the TM shall be turned off.

14.4.3.5 Cal Lamp Filter Temperature

If the calibration lamp filter temperature (TLMPFT) exceeds 55°C the TM shall be turned off.

14.4.4 PRESSURE CONSTRAINTS

The TM inchworms may be energized at ambient pressure or after 3 hours at 10^{-5} torr. The inchworms shall not be energized in the intervening pressure region.

14.4.5 OPERATIONAL CONSTRAINTS

14.4.5.1 Duty Cycle Constraint

The TM shall not support a long term duty cycle in excess of 30% on.

14.4.5.2 Warm Up Time

A warm-up time of less than four minutes is valid only from the standby mode.

14.4.5.3 Attitude Constraints

The TM instantaneous field of view shall not come within ±20° of the sun (see Figure 14.4-1).

The cooler field of view shall not "view" the sun for more than five minutes.

14.4.5.4 Safehold Constraints

If the spacecraft safehold mode is initiated, the TM safehold command sequence shall be executed at the earliest opportunity.

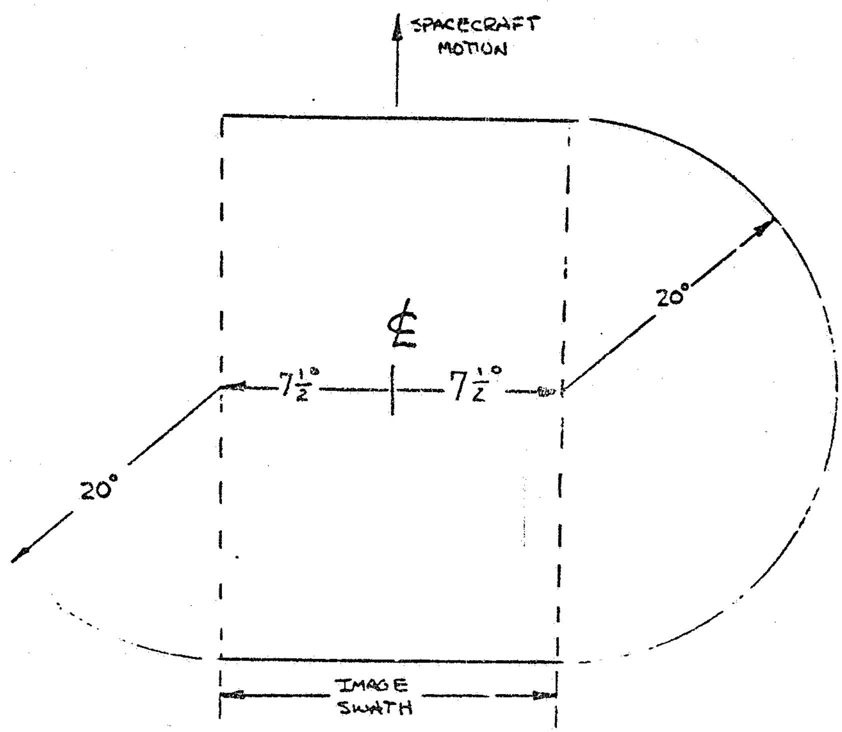

Figure 14.4-1. TM Aperture Sun Avoidance Field

14.5 TM REDUNDANCY AND CROSS-STRAPPING

The Thematic Mapper approach to redundancy is to provide block redundancy for critical components and backup operational modes for less critical components. Redundant components are necessarily cross-strapped. All TM cross-strapping is passive (i.e. selected by command).

14.5.1 REDUNDANT COMPONENTS

The redundant TM components are listed in Table 14.5-1. Each of these components is completely redundant. The command receiver and command generator redundancy is somewhat compromised in that the primary units, interface only with the RIU A unit and the redundant units interface only with the RIU B units (VIZ: these components are redundant but not cross-strapped).

14.5.2 REDUNDANCY FEATURES

The TM contains a number of backup components (see Table 14.5-1). A backup component replaces a prime component but a degradation in performance may result as the backup component is not identical to the component it replaces. A magnetic pickup that senses scan mirror position can be selected to control mirror motion if both scan angle monitors fail. Use of magnetic pickup changes the method of mirror control. A backup shutter is provided that provides the critical DC-restore function of the primary (calibration) shutter but does not provide calibration sources. To utilize the backup shutter, the shutter must be removed from the optical path. This can be accomplished by command but is irreversible. A backup method of opening the cooler door is provided. Once opened by this method the door cannot be moved.

In addition, the TM design provides a number of backup operation modes which minimize the effects of component failures. Some of these design features are listed in Table 14.5-1.

Table 14.5-1. TM Redundant Components

Fully Redundant Components
Scan Mirror Electronics
Scan Angle Monitor
Scan Line Corrector Electronics
Serial Command Receivers
Macro Discrete Command Generators
Power Supplies
Back Up Components
Magnetic Pick
Door Fusible Link
Backup Shutter
Back Up Modes
Manual Calibration Sequencing
Calibration Override Mode
Blackbody Control Modes (3)
CFPA Control Modes (4)
Baffle Temperature Control Modes (2)
DC Restore Selection
Design Features
Individual Electronics for Each Band
Scan Mirror Torquer Redundant for "open" Coils

14.6 THEMATIC MAPPER COMMANDS

Operation of the Thematic Mapper is controlled by 125 commands: 105 Thematic Mapper (TM) Commands; 14 Power Distribution Unit (PDU) commands; and 6 Signal Conditioning and Control Unit (SC&CU) commands. The 105 TM commands are comprised of 63 discrete commands and 42 commands derived from 3 serial command words. The TM commands are listed in Table 14.6-1. The 14 discrete PDU commands affecting the TM are listed in Table 14.6-2. The 6 SC&CU commands affecting the TM, derived from serial command message 470 are listed in Table 14.6-3.

TM commands are described in Paragraph 14.6.1, Standard TM command sequences are described in Paragraph 14.6.2, command restraints appear in Paragraph 14.6.3, and functional command schematics appear in Paragraph 14.6.4.

14.6.1 COMMAND DESCRIPTIONS

The following paragraphs describe the operation of commands affecting the Thematic Mapper. Inter-related commands are discussed in the same paragraph. Command descriptions can be located by referring to the command list (Table 14.6-1).

14.6.1.1 Power Supply Control Commands

The Thematic Mapper has redundant power supplies. Power supply 1 is connected to Instrument Module (IM) power bus A and power supply 2 is supplied by IM bus B. The power supplies are virtually identical and the secondary outputs are diode or-ed to provide power to the TM. The associated telemetry is predominately derived from the or-ed buses. Both supplies have built in protective circuits (viz: over-voltage, under-voltage, inrush current, over temperature, load current, etc.) which affect operation. It is possible to command both supplies on without damage to the system. The TM power supplies are controlled by the following six discrete commands:

Command #	Command Acronym	Command Name
632	PS1ON	Power Supply 1 On
642	PS1OFF	Power SUpply 1 Off
605	PS2ON	Pow r SUpply 2 ON
615	PS2OFF	Power Supply 2 Off
736	THSPNENA	Thermal Shutdown Enable
702	THSDNDIS	Thermal Shutdown Disable

See Page 14-103 for Table 14.6-1

See Page 14-106 for Table 14.6-2

See Page 14-107 for Table 14.6-3

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Command 632, PS1ON, turns on TM power supply 1. Execution of PS1ON momentarily (~6mS) closes power supply relay K4 (see Figure 14.6-1). Closing K4 initiates the pulse stretcher that latches RL1. Latching RL1 connects power bus A to the dc to dc converter through a 10 ohm current limiting resistor. The surge current sensing circuit shorts out the current limiting resistor when the current surge is past and the input voltage is above the lower threshold. The mini switcher and maxi-switcher turn on and provide secondary voltages. Execution of PS1ON requires that Bus A be enabled (ENATMA), since that bus supplies the auxillary regulator that powers the command pulse stretcher. The reciprocal of PS1ON is PS1OFF. Execution of PS1ON can be uniquely verified if power supply 2 is off by the following telemetry responses:

Function	State	Mode
TMPS1I	>10 cnts	--
TM17V	>10 cnts	--
TM127VP	>10 cnts	--
TM127VN	>10 cnts	--

All telemetry functions should also assume nominal values for the operating mode. If power supply 2 is on, power supply 1 will be connected to bus A but will not supply secondary voltages until power supply 2 is turned off.

Command 642, PS1OFF, turns off power supply 1. Execution of PS1OFF momentarily closes power supply relay K5 (see Figure 14.6-1). Closing K5 initiates the pulse stretcher that resets main power relay RL1. Resetting RL1 disconnects power supply 1 from IM bus A. Execution of PS1OFF requires that IM bus A be enabled. The reciprocal of PS1OFF is PS1ON. Execution of PS1OFF produces the following telemetry responses:

Function	State	Mode
TMPS1I	<10 cnts	--
TM17V	<10 cnts	--
TM127VP	<10 cnts	--
TM127VN	<10 cnts	--

Command 605, PS2ON, turns on TM power supply 2. Execution of PS2ON momentarily (~6mS) closes power supply relay K1 (see Figure 14.6-1). Closing K4 initiates the pulse stretcher that latches RL2. Latching RL2 connects power bus B to the dc to dc converter through a 10 ohm current limiting resistor. The surge current sensing circuit shorts out the current limiting resistor when the current surge is past and the input voltage is above the lower threshold. The mini switcher and maxi-switcher turn on and provide secondary voltages. Execution of PS2ON requires that Bus B be enabled (ENATMB), since that bus supplies the auxillary regulator that powers the command pulse stretcher. The reciprocal of PS2ON is PS2OFF. Execution of PS2ON can be uniquely verified if power supply 1 is off by the following telemetry responses:

Function	State	Mode
TMPS2I	>10 cnts	--
TM27V	>10 cnts	--
TM227VP	>10 cnts	--
TM227VN	>10 cnts	--

All telemetry functions should also assume nominal values for the operating mode. If power supply 1 is on, power supply 2 will be connected to bus B but will not supply secondary voltages until power supply 1 is turned off.

Command 615, PS2OFF, turns off power supply 2. Execution of PS2OFF momentarily closes power supply relay K2 (see Figure 14.6-1). Closing K2 initiates the pulse stretcher that resets main power relay RL2. Resetting RL2 disconnects power supply 2 from IM bus B. Execution of PS2OFF requires that IM bus B be enabled. The reciprocal of PS2OFF is PS2ON. Execution of PS2OFF produces the following telemetry responses:

Function	State	Mode
TMPS2I	<10 cnts	--
TM27V	<10 cnts	--
TM227VP	<10 cnts	--
TM227VN	<10 cnts	--

Command 736, THSDNENA, enables the automatic turn off of either power supply if their temperature limit is exceeded. Execution of THSDNENA latches relays K3 and K6 in the mini-switchers. Latching K3 and K6 connects the output of the temperature threshold detector circuit to the shutdown port of the maxi-switcher. If either power supply is on and if its temperature limit ($50^{o}C$) is exceeded, the maxi switcher is inhibited. The reciprocal of THSDNENA is THSDNDIS. Execution of THSDNENA also latches A16K8. Latching A16K8 connects the verification unit +5 volts to the telemetry output. THSDNENA produces the following telemetry response if the TM is on.

Function	State	Mode
TTHSDWN	1	Enabled

Command 702, THSDNDIS, disables the automatic overtemperature shutdown circuits. Execution of THSDNDIS resets mini-switcher relays K3 (PS2) and K6 (PS1) and relay A16K8. Resetting K3 and K6 ground the shutdown port of the maxi-switcher preventing the over temperature circuits from inhibiting the maxi-switcher. Resetting A16K8 grounds the thermal shutdown telemetry point. The reciprocal of THSDNDIS is THSDNENA. Execution of THSDNDIS produces the following telemetry response.

Function	State	Mode
TTHSDWN	0	Disabled

14.6.1.2 Multiplexer Control Commands

Multiplexer operation is controlled by two discrete commands and two serial command messages.

#	Acronym	Name
648	MUX1ON	Power Supply 1 to Mux ON
658	MUX1OFF	Power Supply 1 to Mux Off
621	MUX2ON	Power Supply 2 to Mux On
631	MUX2OFF	Power Supply 2 to Mux Off
870[0003]	MIDSCN	Midscan On
870[0000]	RST870	Reset 870

Command 648 (MUX1ON) turns on the multiplexer, when power supply 1 is On, as shown in Figure 14.6-2. MUX1ON momentarily closes holding relay K2, initiating the pulse stretcher circuit that latches MUX power relay K5. Latching K5 connects the +30 volt output of power supply 1 to the multiplexer power input, turning on the mux. Execution of command 648 requires that power supply 1 be On, to provide power to the pulse stretcher circuit. Command 658, "Power Supply 1 to Mux Off" is the reciprocal or complement to command 648. MUX1ON is not directly verifiable. However, if power supply 1 is on and the command executes correctly, the telemetry functions listed in Table 14.6-4 should be within their ON limits within one major frame, Command 658, MUX1OFF, turns off the multiplexer if it is powered from power supply 1. MUX1OFF momentarily closes holding relay K1 (see Figure 14.6-2), activating the pulse stretcher that resets (unlatches) mux power relay K5. Resetting K5 disconnects the +30 volt output of power supply 1 from the mux power input. Execution of command 658 requires that power supply 1 is ON. Command 648, MUX1ON, is the complement (reciprocal) of command 658. MUX1OFF is not directly verifiable. However, if power supply 1 is powered the multiplexer and if power supply 2 is off or not connected to the multiplexer, then execution of the MUX1OFF command will cause the telemetry

functions listed in Table 14.6-4 to obtain their OFF values, the digital functions to go to zero, and terminate data and clock outputs to the wideband system.

Table 14.6-4. Multiplexer Telemetry Functions

TMUX30V	TM1ADVR
TMUXI	TM2ADVR
TMUX5VP	TM3ADVR
TMUX18VP	TM4ADVR
TMUX3VN	TM5ADVR
TMUX5VN	TM7ACVR
TMUX13VN	

Command 621, MUX2ON, turns the multiplexer on assuming that Power Supply 2 is on. MUX2ON momentarily closes holding relay K4 (see Figure 14.6-2), activating the pulse stretcher that sets mux power relay K6. Setting K6 connects Power Supply 2 +30 volt output to the multiplexer power input. Execution of command 621 requires that Power Supply 2 is ON, to power the pulse stretcher. Command 631, MUX2OFF, is the complement (reciprocal) command. The command MUX2ON is not directly verifiable. However, if Power Supply 2 is on and Power Supply 1 is off or not connected to the multiplexer, execution of MUX2ON will cause the telemetry functions listed in Table 14.6-4 to obtain their ON values. Mux digital telemetry to obtain their on values and date and clock signals to be output to the Wideband Communications Subsystem.

Command 631, MUX2OFF, turns the multiplexer off assuming that it was being powered by Power Supply 2. MUX2OFF momentarily closes holding relay K3 (see Figure 14.6-2), activating the pulse stretcher that resets mux power relay K6. Resetting K6 disconnects the +30 volt output of Power Supply 2 from the mux power input. Command 631, MUX2ON, is the command complement (reciprocal). Execution of the command MUX2OFF requires that Power Supply 2 be ON. MUX2OFF is not directly verifiable. However, if Power Supply 2 is powering the multiplexer and Power Supply 1 is off or not connected to the MUX, execution of MUX2OFF will cause the telemetry functions listed in Table 14.6-4 to obtain their OFF values, digital function to equal zero, and terminate data and clock signals to the Wideband Communications Subsystem.

Command 631, MUX2OFF, turns the multiplexer off assuming that it was being powered by Power Supply 2. MUX2OFF momentarily closes holding relay K3 (see Figure 14.6-2) activating the pulse stretcher that resets mux power relay K6. Resetting K6 disconnects the +30 volt output of Power Supply 2 from the mux power input. Command 621, MUX2ON, is the command complement reciprocal. Execution of the command MUX2OFF require that power supply 2 be ON. MUX2OFF is not directly verifiable. However, if Power Supply 2 is powering the multiplexer and Power Supply 1 is off or not connected to the MUX, execution of MUX2OFF will cause the telemetry functions listed in Table 14.6-4 to obtain their OFF values, digital function to equal zero, and terminate data and clock signals to the Wideband Communications Subsystem.

It should be noted that both TM power supplies can be on and connected to the multiplexer. If this state exists, the verification of single commands may not be possible as the telemetry verifies multiplexer status--not command execution.

Bits 15 and 16 of serial command message 870 control the insertion of the mid scan marker code into the TM data stream. If both bits are decoded as 1's the mid scan marker is inserted into the data stream, otherwise the code is not inserted. The command MIDSCN sets bits 15 and 16 to "ones". The command RST870 sets all the bits in word 870 to "zeros". Command word 870 is received and decoded by the serial command receiver and logic levels corresponding to the command bits are generated for bits 15 and 16. These bits are logically NAND-ed (see Figure 14.6-3) to produce the mid scan marker insertion signal which is utilized in the mux formatter to produce a marker comprised of 48 words of level 255 followed by 48 words of level 0. Command execution requires that the TM be on and the command routed via the RIU that interfaces with the serial command receiver selected.

Execution of MIDSCN is verified if TECHO = 0003, TMIDSCAN = 11, and the midscan marker appears in the data. Command RST870 execution is verified if TECHO = 0000.

14.6.1.3 Scan Mirror Control Commands

The Scan Mirror Assembly (SMA) consists of a oscillating scan mirror driven by a torque motor powered by redundant electronics controlled by redundant position sensors and microprocessors. The scan mirror assembly is temperature controlled at 20 ±2 degrees centigrade.

SMA control is obtained through the following 5 discrete commands and four serial command messages:

Command		
Number	Acronym	Name
748	SME1SEL	SME 1 ON/2 OFF
704	SME2SEL	SME 2 ON/1 OFF
823	SMEOFF	Scan Mirror Electronics Off
750	SAM1SEL	SAM 1 to SME 1
831	SAM2SEL	SAM 2 to SME 2
871(8000)	PSMAENA	SMA +Z Heater Enable
871(4000)	PSMADIS	SMA +Z Heater Disable
871(2000)	NSMAENA	SMA -Z Heater Enable
871(1000)	NSMADIS	SMA -Z Heater Disable

Command 748 (SME1SEL) turns scan mirror electronics (SME) 1 on and SME 2 off. This discrete comamnd resets relays K1 and K2 and latches relay K3 on the SME board (Figure 14.6-4). Resetting K1 connects the scan mirror torque motor to SME 1 motor drive outputs. Resetting K2 connects the $\pm$ 27 volt SME power buses to SME 1. Latching K3 disconnects SME 2 from the $\pm$27 volt buses. If the TM is ON (Power Supply 1 or 2 on), execution of command 748 will result in scan mirror operation. If the TM is OFF execution will configure the SME control relays and scan mirror operation will commence with TM power ON. Command 823, Scan Mirror Electronics Off, is the reciprocal (complementary) command. SME1SEL is verified if TM is ON and TSMESEL = 10.

Command 704 (SME2SEL) turns SME 2 ON and SME1 OFF. This discrete command latches SME relays K1 and K2 and resets relay K3 (Figure 14.6-4). Latching K1 connects SME 2 motor drive outputs to the scan mirror torque motor. Latching K2 disconnects SME 1 from the $\pm$27 volt SME buses. Resetting K3 connects SME 2 to $\pm$27 volt power buses. If the TM is ON, command 704 initiates scan mirror operation from SME 2. If the TM is OFF command 704 configures the SME control relay so that scanning is initiated at TM power ON. Command 823, Scan Mirror Electronics OFF, is the reciprocal (complementary) command. Verification of SME2SEL requires that TM power be ON and that TSMESEL = 01.

Command 823 (SMEOFF) turns off the scan mirror electronics. This discrete command latches SME relays K2 and K3 (see Figure 14.6-4). Latching K2 disconnects SME 1 from the $\pm$27 volt SME power buses. Latching K3 disconnects SME 2 from the power buses. If the TM is ON and scanning, command 823 will turn off the scan mirror electronics and scanning will stop. If the TM is OFF, command 823 will configure the SME relays to off (non-scanning) state. The reciprocal (complementary) commands are SME1SEL and SME2SEL. Verification of SMEOFF requires that TM power be On and that TSMESEL = 00.

Command 750, SAM1SEL, selects Scan Angle Monitor (SAM) 1 as the control element for SME 1 and the magnetic pick-up as the control element for SME 2. Discrete Command 750, resets SME relay K4 (see Figure 14.6-4). Resetting K4 connects SAM 1 signals to the SME 1 microprocessor, and the magnetic pick-up signals to the SME 2 microprocessor. If SME 1 has been selected, the scan mirror will operate in the active scan period control mode, which is a normal operational mode. If SME2 has been selected, the scan mirror will operate in the total period control mode which is a backup mode. THe reciprocal (complement) of command 750 is command 831 which latches K4. Execution of SAM1SEL is verified if TM is On and TSAMSEL = 1.

Command 831, SAM2SEL, selects SAM 2 as the control element for SME 2 and the magnetic pick-up as the control element for SME 1. Discrete command SAM2SEL latches SME relay K4 (see Figure 14.6-4). Latching K4 routes the signals from SAM 2 to SME 2 and the control signals from the magnetic pick-ups to SME 1 micro-processor. If SME 1 has been selected the scan mirror will operate in the fixed total scan period mode and if SME 2 has been selected the scan mirrors will operate in the fixed active scan period control mode. Active scan period mode is the normal operating mode and fixed total period is the backup, mode. The reciprocal (complement) of command 831 is command 750 which resets K4. Execution of SAM2SEL is verified if TM is On and TSAMSEL = 0.

Serial Command 871, message 8000 (PSMAENA), enables the heater controller that maintains the +Z end of the scan mirror assembly (SMA) frame at 20 ± 2 degrees centigrade ($^{\circ}C$). Command PSMAENA resets relay A5K1 and latches relay A16K6. Resetting A5K1 connects the ± 19 volt buses to the ± 12 volt regulator which powers the +Z SMA temperature controller (see Figure 14.6-5). Latching A16K6 provides an enable signal to the controller. When enabled, the temeprature controller senses (by thermistor) the temperature of the +Z end of the scan mirror frame and turns a 25 ohm resistive heater on and off as required to maintain the temperature at 20 ± 2 degrees centigrade ($^{\circ}C$). The heater is powered by IM bus A/B which must be enabled (PDU command). In order for the +Z SMA temperature controller to operate the TM must be enabled. Execution of PSMAENA requires that the TM micro-discrete command generator (MDCG) A be on and the command routed via the RIU (A or B) which interfaces with MDCG selected. The reciprocal (complement) of PSMAENA is serial command 871 message 4000. PSMAENA is verified if TM is On and TSMASTAT = **11, where * indicates either 1 or Ø.

Serial command 871, message 4000 (PSMADIS), disables the heater control circuitry that maintains the +Z end of the SMA frame at 20 $\pm 2^{\circ}C$. PSMADIS latches relay A5K1 and resets relay A16K6. Latching A5K1 disconnects the ± 19 volt buses from the ± 12 volt regulator that powers the ON/OFF controller. Resetting A16K6 removes the enable signal (ground) from the controller. With the power and enable signal removed the +Z heater is off. Execution of PSMADIS requires that Macrodiscrete Command Generator A (prime or redundant be on and that the command be routed through the RIU side (A or B) that interfaces with the active command generator. The reciprocal (complement) to 871 message (4000) is 871 message (8000). Verification of PSMADIS requires that TM be on and TSMASTAT = **00, where * indicates either a 1 or Ø.

Serial Command 871 message 2000 (NSMAENA) enables the heater control circuitry that maintains the -Z end of the SMA frame at 20 $\pm 2^{\circ}$C. NSMAENA latches relays A5K5 and A16K7. Latching A5K5 connects the $\pm$15 volt buses to the regulator which poweres the coutroller. Latching A16K7 provides the enable signal (ground) to the controller. When enabled the controller senses the temperature of the -Z end of the scan mirror frame and turns the resistive heater (25 ohms) on or off to control the temperature. The heater power is obtained from the Instrument Module A/B bus which must be enabled (PDU function) for SMA heater operation. Execution of NSMAENA requires that macrodiscrete command generator A be on (prime or redundant) and that the command be routed via the RIU (A or B) that interfaces with the selected command generator. The command recripocal (complement) to 871 (2000) is 871 (1000). Execution of NSMAENA is verified if TSMASTAT = 11**, where * indicates either 1 or Ø.

Serial command 871 message 1000 (NSMADIS) disables the heater control circuitry that maintains the temeprature of the -Z end of the scan mirror frame. NSMADIS resets relays A5K5 and A16K7. Resetting A5K5 disconnects the $\pm$19 volt buses from the regulator that powers the -Z heater control circuits. Resetting A16K7 disconnects the enable signal from the control circuit. With A5K5 and A16K2 reset the -Z SMA heater is off, and active temperature control is not maintained. Execution of NSMADIS requires that macrodiscrete command generator A be on (either prime or redundant) and that the command be routed via the RIU side (A or B) which interfaces with the selected command generator. The reciprocal of NSMADIS is NSMAENA. Verification of NSMADIS requires that TM power be On and TSMASTAT = 00**, where * indicates 1 or Ø.

14.6.1.4 Shutter Control Commands

The design of the TM utilizes an oscillating shutter which obscures the field of view so that dc restoration may be performed. Two shutters are provided: A primary shutter, which blocks the field of view and provides stimuli for internal check of calibration; and a backup shutter which only obscures the field of view. The primary or calibration shutter blocks the field of view in its rest position and when operating blocks the field of view twice per shutter cycle at the end of each mirror sweep during the turn-around interval. The shutter operation is syncnronized (phase and amplitude) to the mirror end-of-scan pulse. During the obscuration period the multiplexer buffer amplifiers are set to level 2 1/2 $\pm$1/2 except for the band 6 buffers which are set to a level corresponding to the shutter temperature. A backup shutter is provided in the event that the primary shutter fails. The backup shutter contains no stimuli and hence provides dc restoration only. The reset position of the backup shutter does not obscure the field of view. In order to use the backup shutter the primary shutter must be removed from the field of view. A fusible link operated mechanism provides this capability and upon execution of the appropriate command sequence the calibration shutter is permanently removed from the field of view and cannot be operated.

Shutter operation is controlled by the following three discrete commands and four serial command messages:

Command		
Number	Acronym	Name
706	CSHTRON	Calibration Shutter On
803	BUSHTRON	Backup Shutter On
839	SHTROFF	Both Sutters OFf
871(0080)	SFLARM	Arm Shutter Fuse Link
872(0008)	SFLENA	Enable Shutter Fuse Link
872(0002)	SFLFIRE	Fire Shutter Fuse Link
872(0001)	FLSAPE	Safe Fuse Links

Command 706 (CSHTRON) turns on the calibration shutter and turns the backup shutter off. Execution of CSHTRON resets relays A6K1, A6K2, A8K1 and latches relays A7K1, A7K2 and A5K3 (see Figure 14.6-6). Resetting relay A7K1 connects the +33 volt bus to the shutter drive circuits and the +8 volt bus to the +5 volt regulator that powers the shutter drive logic. Resetting A7K2 connects the ±19 volt buses to the −5 volt regulator that provides power to the motor drive circuits. Resetting A8K1 sets the dc restore signal to normal which selects one of the two shutter temperature-derived signals to be utilized for band 6 dc restore. Latching relay A7K1 disconnects the +8 and +33 volt buses from the backup shutter control circuits and latching A7K2 disconnects the ±19 volt buses. Latching relay A5K3 selects the dc restore signal derived form the calibration shutter temperature. Commands SHTROFF and BUSHTRON are recriprocal (complements) of command CSHTRON. SHTROFF should be used to turn off the calibration shutter and BUSHTRON should be used to turn on the backup shutter.

Execution of CSHTRON produces the following telemetry responses:

Function	State	Mode
TBUSHTR	000	OFF
TCALSHTR	1**	ON
TCALSHTR	111	ON IN LOCK requires 5 mjf

* dont care 1 or 0

Command 803 (BUSHTRON) turns off the calibration shutter and turns on the backup shutter. Execution of the Command BUSHTRON resets relays A5K3, A7K1, A7K2, A8K1 and latches relays A6K1, and A6K2. Latching A6K1 and K2 disconnects the +8, +33, +19 and -19 volt buses from the calibration shutter drive and control circuits. Resetting A7K1 and K2 connects +33 volts to the backup shutter motor drive circuits, connects +8 volts to the +5 volt regulator that provides power to the shutter drive logic and connects the $\pm$19 volt buses to the -5 volt regulator that provides power to the backup shutter motor control circuits. Resetting A8K1 and A5K3 selects the backup shutter temperature-derived signal from band 6 dc restore. Commands CSHTRON and SHTROFF are reciprocals (complements) to CSHTRON. Verification of BUSHTRON requires that TBUSHTR = 1** within 1 major frame and TBUSHTR = 111 and TCALSHTR = 000 within 5 major frames.

Command 839 (SHTROFF) turns off both (either) shutter. Execution of SHTROFF latches relays A6K1, A6K2, A7K1 and A7K2 (see Figure 14.6-6). Latching relays A6K1 and K2 disconnects the +33, +19, -19 and +8 volt buses from the backup shutter motor drive and control circuits. Latching A7K1 and K2 disconnects the +33, +19, -19 and +8 volt buses from the backup shutter motor drive and control circuits. The commands CSHTRON and BUSHTRON are reciprocals (complements) to SHTROFF. Verification of SHTROFF requires that TM be on and both TCALSHTR = 000 and TBUSHTR = 000.

Command 872 message 0008 (SFLENA) enables the shutter fuse link command. Execution of SFLENA resets relay A8K4, which connects the combined command pulse bus to the reset coil of relay A8K6 (see Figure 14.6-7). Execution of SLFENA requires that macrodiscrete command generator B (prime or redundant) be ON and the serial command message be routed via the RIU side (A or B) that interfaces with the active command generator. FLSAFE is the reciprocal (complement) to SLFENA. Execution of SFLENA is verified if TSHRFZLK = 100.

Command 871 message 0080 (SLFARM) arms the shutter fuse link. SFLARM execution latches relay A8K6. Latching relay A8K6 connects the combined command pulse bus to the latch coil of relay A8K8, permitting the execution of command SFLFIRE.

Execution of SFLARM requires that: (1) macrodiscrete command generator A be ON (prime or redundant) (2) the command message be routed via the RIU side (A or B) that interfaces with the active command generator (see Paragraph 14.6.1.10) and (3) command SLFENA be executed prior to execution of SLFARM. Command FLSAFE is the reciprocal (complement) to SFLARM. Execution of SFLARM is verified if TSHRFZLK = 110.

Command 872 message 0002 (SFLFIRE) activates the fusible link which permanently removes the calibration shutter from the TM optical path. Execution of SFLFIRE resets relay A8K8. Resetting A8K8 turns on the transistor switches which connect IM bus voltage to the fusible link heater (see Figure 14.6-7). The fusible link subsequently softens, releasing the spring which extracts the calibration shutter from the field of view. Softening of the fusible links requires approximately TBD seconds and is dependent upon IM bus voltage. Fusible link activation is irreversible. Execution of SFLFIRE requires that: (1) macrodiscrete command geneartor B is ON (prime or redundant), (2) the command message is routed to the RIU side (A or B) that interfaces with the active command generator (see Paragraph 14.6.1.10); and (3) the shutter fuselink is armed (execution of SFLARM command). Command FLSAFE is the reciprocal (complement) to SFLFIRE in the sense that it latches relay A8K8 but is does not re-activate the calibration shutter. Execution of SFLFIRE is verified if TSHRFZLKC = 111.

Command 872 message 0001 (FLSAFE) disables fuse link operation. Execution of FLSAFE latches relays A8K3, A8K4, A8K54, A8K6, A8K7 and A8K8 (see Figure 14.6-7 and 14.6-18). Latching A8K7 and A8K8 disconnects IM bus power from the switches that control the cooler door and calibration shutter fusible link heaters. Latching A8K5 and A8K6 disconnects the outputs of those relays from the latch coils of A8K7 and A8K8. Latching A8K3 and A8K4 disconnects the combined command pulse bus from the latching coils of relays A8K5 and A8K6. Execution of FLSAFE requires that (1) microdiscrete command generator B is on, and (2) the command message is routed via the RIU (A or B) that interfaces with the active command generator (see Paragraph 14.6.1.10). Execution of FLSAFE is verified if TSHRFZLK = 000, TDRFZLK = 000 and TM is On.

14.6.1.5 Calibration Lamp Control

Internal check of calibration for bands one through five and seven is provided by three incandescent lamps. The radiance from the three lamps is combined and routed via fiber optics to the flag mounted on the calibration shutter. The shutter motion sweeps the calibration stimuli across the focal plane at the end of each mirror scan. The lamps can be controlled individually or in an automatic sequence, and in a controlled radiance or constant voltage mode. Calibration lamp control is obtained by the following commands:

	Command	
Number	Acronym	Name
708	LP1ON	Cal Lamp #1 ON
712	LP2ON	Cal Lamp #2 ON
714	LP3OFF	Cal Lamp #3 OFF
734	LP2OFF	Cal Lamp #2 OFF
738	LP1OFF	Cal Lamp #1 OFF
740	LP3ON	Cal Lamp #3 ON
807	LP2ORON	Cal Lamp #2 Override ON
809	LP1ORON	Cal Lamp #1 Override ON
833	LP3ORON	Cal Lamp #3 Override ON
871(0008)	SEQON	Lamp Sequencer ON
871(0004)	SEQOFF	Lamp Sequencer OFF

Command 708 (LP1ON) turns on calibration lamp 1 in the radiance controlled mode. Execution of LP1ON resets relay A3K1 (see Figure 14.6-8). Resetting A3K1 connects the plus and minus 19 volt buses to the cal lamp 1 ±12 volt regulator. The lamp controller applies power to the lamp and senese the lamp output using a photo-diode. The lamp current is controlled so that the photo-diode output is constant. Lamp 1 is controlled to produce a radiance at each detector of ~ 40% full scale. If the lamp sequencer is ON, cal lamp 1 is turned ON and OFF by the sequencer. Command LP1OFF is the reciprocal (complement) to LP1ON. Execution of LP1ON is verified if TLMPSTAT = 10*****.

Command 712 (LP2ON) turns on calibration lamp #2. Execution of LP2ON resets relay A3K3 which connects the plus and minus 19 volt buses to the Lamp 2 ±12 volt regulator (see Figure 14.6-8). With power applied to the controller calibration lamp 2 operates in the normal mode with lamp out controlled by the photo-diode that senses lamp radiance. If the lamp sequencer is off, calibration lamp #2 will be on and producing approximately 30% full scale output in each channel. If the sequencer is on, cal lamp 2 will be cycled on and off, at 30% radiance, under sequencer control. Command LP2OFF is the reciprocal (complement) of LP2ON. Execution of LP2ON is verified if TLMPSTAT = **10***.

Command 714 (LP3OFF) turns off calibration lamp #3. Execution of LP3OFF resets relay A3K6 and latches relay A3K5 (see Figure 14.6-8). Latching relay A3K5 disconnects the $\pm$19 volt buses from the calibration lamp #3 controller. Resetting A3K6 connects calibration lamp #3 return to the radiance control circuit. Command LP3OFF is the reciprocal (complement) to commands LP3ON and LP3ORON. Execution of LP3OFF is verified if TM is on and TLMPSTAT = ****00*.

Command 734 (LP2OFF) turns off calibration lamp #2. Execution of LP2OFF latches relay A3K3 and resets relay A3K4 (see Figure 14.6-8). Latching relay A3K3 disconnects the lamp 2 controller from the $\pm$19 volt buses. Resetting relay A3K4 connects the return for calibration lamp #2 to the proportional radiance controller. Command LP2OFF is the reciprocal (complement) to commands LP2ON and LP2ORON. Execution of LP2OFF is verified if TM is on and TLMPSTAT = **00***.

Command 738, LP1OFF, turns off calibration lamp #1. Execution of LP1OFF latches relay A3K1 and resets relay A3K2 (see Figure 14.6-8). Latching relay A3K1 cisconnects the $\pm$19 volt buses form the calibration lamp #1 controller. Resetting A3K2 connects the return for cal lamp #1 to its proportional radiance controller. Command LP1OFF is the reciprocal (complement) to commands LP1ON and LP1ORON. Execution of LP1OFF is verified if TM is on and TLMPSTAT = 00*****.

Command 740, LP3ON, turns off calibration lamp #3. Execution of LP3ON resets relay A3K5 (see Figure 14.6-8) which connects the $\pm$19 volt buses to the regulator that powers cal lamp 3 and its controller. With power applied, lamp 3 operates. In the normal mode lamp 3 is controlled by a photo-diode that senses lamp output. If the sequencer is off, lamp 3 will be on and produce an output which provides approximately 20% full scale in each channel. If the sequencer is on, lamp 3 is turned on (@ 20%) and off as required by the sequencer. Command LP3ON is the reciprocal (complement) to LP3OFF. Execution of LP3ON is verified if TLMPSTAT = ****10*.

Command 807, LP2ORON, places calibration lamp #2 in the backup control mode. Execution of LP2ORON latches relay A3K4 (see Figure 14.6-8). Latching relay A3K4 connects the return of calibration lamp 2 to ground through a fixed resistance. If power is applied (LP2ON) the lamp is ON in the constant current mode and the sequencer and photo-diode control loop have no affect upon operation. The reciprocal (complement) of LP2ORON is LP2OFF. Execution of LP2ORON is verified if TLMPSTAT = **11***.

Command 809, LP1ORON, places calibration lamp 1 in the backup control mode. Execution of LP1ORON latches relay A3K2 (see Figure 14.6-8). Latching relay A3K2 connects the return for calibration lamp #1 to ground through a fixed resistance and, hence, the lamp operates in a constant-current mode. In this backup control mode, the lamp is on if power is applied and the sequencer has no effect upon lamp 1 operation. The command LP1OFF is the complement (reciprocal) to LP1ORON. Execution of LP1ORON is verified if TLMPSTAT = 11*****.

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Command 833, LP3ORON, places calibration lamp 3 in the backup control mode. Execution of LP3ORON latches relay A3K6. Latching relay A3K6 connects the return of calibration lamp 3 to ground through a fixed resistance (see Figure 14.6-8), thus placing the lamp in the constant-current mode. If power is applied in this mode, the lamp is always on and unaffected by the sequencer. Command LP3OFF is the reciprocal (complement) of LP3ORON. Execution of LP3ORON is verified if TLMPSTAT = ****11*.

Command 871 message 0008 (SEQON) turns on the calibration lamp sequencer. Execution of SEQON resets relay A8K9. Resetting A8K9 (see Figure 14.6-9) connects the +8 volt bus to the +5 volt regulator that powers the calibration sequencer. With the sequencer on and the cal lamps on in the normal mode, the sequencer turns the lamps on and off as shown in the following table:

Sequence State	Lamps ON	% Full Scale
1	-	0
2	1	40%
3	1,2	70%
4	2	30%
5	2,3	50%
6	1,2,3	90%
7	1,3	60%
8	3	20%

Each state exists for 40 sweeps or approximately 2.86 seconds. The sequence repeats until the sequencer is turned off. The sequencer actually turns lamps off by inserting control signals in the radiance feedback loops and hence requires the lamps to be in the normal mode. Command SEQOFF is the reciprocal (complement) of SEQON. Execution of SEQON requires that (1) Macro-discrete command generator A be ON (prime or redundant) and (2) the command message be routed via the RIU (A or B) that interfaces with the active command generator. Execution of SEQON is verified if TLMPSTAT = ******1.

Command 871 message 0004 (SEQOFF) turns off the calibration lamp sequences. Execution of SEQOFF latches relay A8K9. Latching A8K9 disconnects the sequencer regulator from the +8 volt bus (see Figure 14.6-9). When the sequencer is off, the lamp operation is controlled by the ON and OFF commands. Execution of SEQOFF requires that (1) macro-discrete command generator A be on (prime or redundant) and (2) the command message be routed via the RIU (A or B) that interfaces with the active command generator. Command SEQON is the reciprocal (complement) of SEQOFF. Execution of SEQOFF is verified if TM is on and TLMPSTAT = ******0.

14.6.1.6 Cold Focal Plane Array Temperature Control

The Cold Focal Plane Array (CFPA) is comprised of the band 5, 6 and 7 detectors. In-specification performance of these detectors requires stable low temperatures. In-orbit cooling is provided by a passive radative cooler which provides a CFPA temperature of less than 90^{o} Kelvin (K). Three controlled operating temperatures (90^{o}, 95^{o} and 105^{o}K) are provided by the CFPA temperature controller. The controller utilizes silicon diodes as the temperature sensing element in a proportional controller to operate a 3500 ohm deposited heater on the CFPA substrate. The commands used to control CFPA temperature are:

Command Number	Acronym	Name
710	CFPAONT1	CFPA Controller ON T1 Select
720	CFPATMOF	CFPA Telemetry Off
744	CFPAOFF	CFPA Controller Off
805	CFPA2SEL	CFPA Select T2
811	CFPA3SEL	CFPA Select T3

Command 710 (CFPAONT1) turns on the CFPA temperature controller and selects set point T1 (90^{o}K). Execution of CFPAONT1 resets relay A4K5 and latches relays A4K6, A4K7 and A4K8 (see Figure 14.6-10). Latching relay A4K6 connects the + and - 19 volt buses to the CPFA $\pm$15 volt regulator that powers the temperature sensing and monitoring (telemetry) circuits. Resetting A4K5 connects the output of the $\pm$15 volt regulator to the proportion temperature controller. Latching A4K7 and A4K8 select temperature control point T1 by not shorting resistors in the reference voltage generator. CFPAONT1 has no reciprocal command. Execution of CFPONT1 produces the following telemetry responses.

Function	State	Mode
TCFPA	1001	ONT1
TCFPACT	>2 Cnts	--
TCFPAMT	>2 Cnts	--

Command 720 (CFPATMOF) turns off the CFPA temperature monitor and control circuitry. Execution of CFPATMOF resets relay A4K6 (see Figure 14.6-10). Resetting A4K6 disconnects the + and - 19 volt buses from the CFPA regulator, thus removing all power to the CFPA. Command CFPAONT1 is the reciprocal

(complement) to CFPATMOF. Execution of CFPATMOF produces the following telemetry responses if Tm power is on.

Function	State	Mode
TCFPA	0000	OFF
TCFPACT	$\leq$0 Cnts	--
TCFPAMT	$\leq$0 Cnts	--

Command 744 (CFPAOFF) disables the CFPA heater control circuits. Execution of CFPAOFF latches relay A4K5 (see Figure 14.6-10). Latching A4K5 disconnects the outputs of the + and - 15 volt CFPA regulator from the heater control circuits. Command CFPAONT1 is the reciprocal (complement) to CFPAOFF. Execution of CFPAOFF is verified if TCFPA = 0**1, where * = don't care 1 or Ø.

Command 805 (CFPA2SEL) selects CFPA temperature control point T2 (95°K). Execution of CFPA2SEL resets relay A4K8 (see Figure 14.6-10). Resetting A4K8 changes the reference voltage to the voltage comparator by shorting, to ground a resistor in the divider. CFPA2SEL is not effective if control point T3 has been selected. Command CFPAONT1 is the reciprocal to CFPA2SEL. Execution of CFPA2SEL is verified if TCFPA = *1*1. If TM is off or the CFPA temperature monitor and controller is off, CFPA2SEL cannot be verified.

Command 811, CFPA3SEL, selects CFPA temperature control point T3 (105°K). Execution of CFPA3SEL resets relay A4K7 (see Figure 14.6-10). Resetting A4K7 changes the reference voltage presented to the voltage comparator by shorting a resistor in the divider to ground. CFPA3SEL overrides CFPA2SEL and precludes utilization of set point T2 until CFPACNT1 is executed. Command CFPAONT1 is the reciprocal of CFPA3SEL. Verification of CFPA3SEL execution requires that TM be on, the CFPA telemetry be on, and TCFPA = **11.

14.6.1.7 Blackbody Temperature Control

On-board check of calibration for band 6 is provided by a conical-shaped, temprature-controlled blackbody. The blackbody is "viewed" once each sweep, during mirror turnaround, via a mirror on the calibration shutter. The temperature of the blackbody can be maintained at any of three set points using the closed-loop proportional control. The blackbody heater (75 ohms) can also be operated in the constant power (backup) mode. The blackbody temperature monitor and control circuits are powered from the full-time + and - 19 volt buses. The commands that provide blockbody temperature control are:

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Command Number	Acronym	Name
716	BBHTRENA	BB Heater Enable
746	BBHTRDIS	BB Heater Disable
813	BBT2SEL	BB Select T2
817	BBBKUPON	BB Backup Mode
835	BBT3SEL	BB Select T3

Command 716, BBHTRENA, turns on the blackbody temperature sensing and control circuits. Execution of BBHTRENA resets relays A4K1, A4K2 and latches A4K3 (see Figure 14.6-11). Latching A4K3 connects the + and - 19 volt full-time buses to the + and - 12 volt regulators that power the blackbody temperature sensing and control circuits. Resetting A4K1 and A4K2 selects temperature control point T1 (24°C) by removing the grounds in the reference voltage divider. If the ±19 volt buses are powered, the blackbody temperature is sensed by a thermistor voltage divider and compared to T1 reference voltage; the blackbody heater current is proportionately controlled to maintain the set point temperature if the controller is in the NORMAL mode. The command BBHTRENA has no complete reciprocal command but BBHTRDIS resets A4K3. Execution of BBHTRENA activates the blackbody heater current telemetry (TM53) and is verified if TBBSET = 100*.

Command 746, BBHTRDIS, turns off the blackbody temperature controller and returns it to the NORMAL mode. Execution of BBHTRDIS resets relays A4K3 and A4K4 (see Figure 14.6-11). Resetting A4K3 disconnects the ±12 volt regulator that powers the controller from the + and - 19 volt full-time buses. Resetting A4K4 connects the blackbody heater return to the proportional controller. Commands BBHTRENA and BBBKUPON are reciprocal commands. Execution of BBHTRDIS disables the blackbody heater current telemetry (TM-53) and is verified if TBBSET = 0000 when TM is on.

Command 813, BBT2SEL, selects blackbody temperature control point T2 (~30°C). Execution of BBT2SEL latches relay A4K2 (see Figure 14.6-11). Latching K2 grounds the T2 tap on the reference voltage divider causing the proportional controller to operate at the T2 set point. Execution of BBT2SEL cannot change the control point from T3 to T2. To insure proper configuration command BBHTRENA should be executed prior to execution of BBT2SEL. The command BBHTRENA is the reciprocal to BBT2SEL. Verification of BBT2SEL requires that TBBSET = 11** and TM power be on.

Command 817, BBBKUPON, selects the constant power mode of blackbody temperature control. Execution of BBBKUPON latches A4K4 (see Figure 14.6-11). Latch A4K4 connects the blackbody heater return to ground through a fixed resistance. As a result, when energized, the heater will be operated at a constant power rather than at a controlled temperature. The BBBKUPON command overrides BBT2SEL and BBT3SEL. BBHTRDIS command is the reciprocal of BBBKUPON. Execution of BBBKUPON is verified if TBBSET = 1**1 and TBBHTRI > 20 counts. BBBUPON cannot be verified if TM power is off.

Command 835, BBT3SEL, selects the T3 (35^{o}C) temperature set point for control of the blackbody heater. Execution of BBT3SEL latches relay A4K1 (see Figure 14.6-11). Latching A4K1 grounds the T3 top on the reference voltage generator of the controller selectiong T3 overrides and precludes selection of set point T2. Selection of T3 is inhibited by selectin of the backup mode Command BBHTRENA is the reciprocal of BBT3SEL. BBT3SEL verification requires TM power to be on and TBBSET = 1*1*.

14.6.1.8 Band Selection

The Thematic Mapper quantifies data in seven spectral bands. Each band can be energized separately and, except for bands 5 and 7, have individual power supply outputs. The commands that select operating bands are:

	Command	
Name	Acronym	Name
718	BD1ON	Band 1 ON
724	BD2OFF	Band 2 OFF
728	BD3ON	Band 3 ON
730	BD4OFF	Band 4 OFF
752	BD1OFF	Band 1 OFF
754	BD2ON	Band 2 ON
756	BD3OFF	Band 3 OFF
758	BD4ON	Band 4 ON
815	BD7ON	Band 7 ON
819	BD5ON	Band 5 ON
825	BD6OFF	Band 6 OFF
841	BD7OFF	Band 7 OFF
845	BD5OFF	Band 5 OFF
847	BD6ON	Band 6 ON

Command 718, BD1ON, turns on the detectors, preamps and postamps comprising the 16 channels of band 1. Execution of BD1ON resets relays A21K1, A21K2 and A21K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four $\pm$15 volt regulators that provide the power for the band electronics. The reciprocal of BD1ON is BD1OFF. Verification of BD1ON requires that TM be on and TBNDSTAT = 1******.

Command 752, BD1OFF, turns on the detectors, preamps and postamps comprising the 16 channels of band 1. Execution of BD1OFF resets relays A21K1, A2K2 and A21K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four ±15 volt regulators that provide the power for the band electronics. The reciprocal of BD1OFF is BD1ON. Verification of BD1OFF execution requires that TM be on and TBNDSTAT = Ø******.

Command 754, BD2ON, turns on the detectors, preamps and postamps omprising the 16 channels of band 2. Execution of BD2ON resets relays A20K1, A20K2 and A20K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four ±15 volt regulators that provide the power for the band electronics. The reciprocal to BD2ON is BD2OFF. Verification of BD2ON execution requires that TM be on and that TBNDSTAT = *1*****.

Command 724, BD2OFF, turns on the detectors, preamps and postamps comprising the 16 channels of band 2. Execution of BD2OFF resets relays A20K1, A20K2 and A20K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four ±15 volt regulators that provide the power for the band electronics. The reciprocal of BD2OFF is BD2ON. Verification of BD2OFF execution requires that TM be on and that TBNDSTAT = *0*****.

Command 728, BD3ON, turns on the detectors, preamps and postamps comprising the 16 channels of band 3. Execution of BD3ON resets relays A19K1, A19K2 and A19K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four ±15 volt regulators that provide the power for the band electronics. The reciprocal to BD3ON is BD3OFF. Verification of BD3ON execution requires that the TM be on and that TBNDSTAT = **1****.

Command 756, BD3OFF, turns on the detectors, preamps and postamps comprising the 16 channels of band 3. Execution of BD3OFF resets relays A19K1, A19K2 and A19K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four ±15 volt regulators that provide the power for the band electronics. The reciprocal of BD3OFF is BD3ON. Verification of BD3OFF execution requires that the TM be on and that TBNDSTAT = **0****.

Command 758, BD4ON, turns on the detectors, preamps and postamps comprising the 16 channels of band 4. Execution of BD4ON resets relays A18K1, A18K2 and A18K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four ±15 volt regulators that provide the power for the band electronics. The reciprocal of BD4ON is BD4OFF. Verification of BD4ON execution requires that the TM be on and that TBNDSTAT = ***1***.

Command 730, BD4OFF, turns on the detectors, preamps and postamps comprising the 16 channels of band 4. Execution of BD4OFF resets relays A18K1, A18K2 and A18K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four ±15 volt regulators that provide the power for the band electronics. The reciprocal of BD4OFF is BD4ON. Verification of BD4OFF execution requires that the TM be on and that TBNDSTAT = ***0***.

Command 819, BD5ON, turns on the detectors, preamps and postamps comprising the 16 channels of band 5. Execution of BD5ON resets relays A17K1, A17K2 and A17K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four $\pm$15 volt regulators that provide the power for the band electronics. The reciprocal of BD5ON is BD5OFF. Verification of BD5ON execution requires that the TM be on ;and that TBNDSTAT = ****1**.

Command 845, BD5OFF, turns on the detectors, preamps and postamps comprising the 16 channels of band 5. Execution of BD5OFF resets relays A17K1, A17K2 and A17K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four $\pm$15 volt regulators that provide the power for the band electronics. The reciprocal of BD5OFF is BD5ON. Verification of BN5OFF execution requires that the TM be on and that TBNDSTAT = ****0**.

Command 847, BD6ON, turns on the detectors, preamps and postamps comprising the 16 channels of band 6. Execution of BD6ON resets relays A16K1, A16K2 and A16K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four $\pm$15 volt regulators that provide the power for the band electronics. The reciprocal of BD6ON is BD6OFF. Verification of BP6ON execution requires that the TM be on and that TBNDSTAT = *****1*.

Command 825, BD6OFF, turns on the detectors, preamps and postamps comprising the 16 channels of band 6. Execution of BD6OFF resets relays A16K1, A16K2 and A16K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four $\pm$15 volt regulators that provide the power for the band electronics. The reciprocal of BD6OFF is BD6ON. Verification of BD6OFF execution requires that the TM be on and that TBNDSTAT = *****0*.

Command 815, BD7ON, turns on the detectors, preamps and postamps comprising the 16 channels of band 7. Execution of BD7ON resets relays A15K1, A15K2 and A15K3 (see Figure 14.6-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four $\pm$15 volt regulators that provide the power for the band electronics. The reciprocal of BD7ON is BD7OFF. Verification of BD7ON execution requires that the TM be on and that TBNDSTAT = ******1.

Command 841, BD7OFF, turns on the detectors, preamps and postamps comprising the 16 channels of band 7. Execution of BD7OFF resets relays A15K1, A15K2 and A15K3 (see Figure 14.6.4-12). Resetting relays K1, K2 and K3 connects the + and - 19 volt band buses to the four $\pm$15 volt regulators that provide the power for the band electronics. The reciprocal to BD7OFF is BD7ON. Verification of BD7OFF execution requires that the TM be on and TBNDSTAT = ******0.

14.6.1.9 Cooler Door Control

The Thematic Mapper radiative cooler door can be commanded to any of three positions: closed, outgas (a position about 3 degrees from closed), and full open (a position about 90 degrees from closed). To move the door, the following steps are required: (1) command the door motor drive on, (2) select the direction of motion, and (3) execute a move enable command. There are three micro switches on the door assembly: one at the closed position, one at the outgas position and one at the full open position. Once the move enable command is executed, the 400 Hz motor drive is applied until any of the three microswitch are closed or until 15 seconds have elapsed. The microswitches position logic is disabled for the initial 1.5 seconds of drive to enable the door to move. The door motor assembly contains a brake which is disengaged during the application of motor drive.

In the event of a motor or motor drive failure, the door can be moved--once--to the full open position by actuating the door fusible link. Activation of the fusible link is irreversible.

The cooler door shall be secured during launch and during periods of vibration. Securing the door consists of closing the door and turning on the door electromagnets which hold the door in the closed position. The door magnets consume approximately 12 watts of power and should be turned off upon completion of launch.

Control of the cooler door is accomplished through utilization of the following commands:

Command Number	Command Acronym	Command Name
722	DMAGON	Door Magnet On
732	DMAGOFF	Door Magnet Off
870[0008]	DOROPN	Open Cooler Door
870[000C]	DORCLS	Close Cooler Door
871[0100]	DFLARM	Arm Door Fuse Link
872[4000]	DMTRON	Door Motor On
872[2000]	DMTROFF	Door Motor Off
872[0040]	DFLENA	Enable Door Fuse Link
872[0010]	DFLFIRE	Fire Door Fuse Link
872[0001]	FLSAFE	Fuselink Safe

Command 722, DMAGON, turns on the cooler door electromagnet. Execution of DMAGON latches relays A16K10 and A16K11 (see Figure 14.6-13). Latching A16K10 and K11 connects IM bus A/B to the door electro-magnets. If the SMA and door latch power are enabled, the magnets are energized and the door is held shut. DMAGOFF is the reciprocal to DMAGON.

Command 732, DMAGOFF, turns off the cooler door magnet power and selects the frame-temperature-derived dc restore signal for Band 6. Execution of DMAGOFF resets relays A16K10 and A16K11, and latches A8K1. Resetting A16K10 and K11 disconnects the IM A/B bus from the cooler door electro-magnet (see Figure 14.6-13). Turning off the magnet power "unlatches" the door, allowing it to be opened. Latching A8K1 selects the shutter frame-temperature-derived signal as the source of the band 6 dc restoration (see Figure 14.6-17). DC restore and cooler door functions are not related but the commands were combined to minimize the number of commands. The reciprocals to DMAGOFF is DMAGON.

Command 870 messages are received and decoded by the TM serial command receiver. The decoding produces 16 logic levels equivalent to 16 bit states of the command message. These 16 logic levels are buffered and routed to the appropriate circuits. Bit #13 is routed to the door logic circuit (see Figure 14.6-14). A logic zero inhibits the 1.5 and 15 second one-shots from initiating the door motion sequence. A logic one releases the one-shot and initiates the door motion. Bit #14 is also routed to the door logic circuits (see Figure 14.6-14). The state of bit #14 is exclusive or-ed with the timing signals to change motor direction. A logic zero causes the motor to move the door in the open direction, and a logic 1 causes the motor to move the door in the close direction.

Command 870[0008], DOROPN, causes the cooler door to move to the next open position, if the door motor is on. Execution of DOROPN provides a door enable and an open direction signal to the door logic circuits. Execution of DOROPN requires that DMTRON has been executed. The reciprical command is RST870. DOROPN is verified by TECHO = 0008.

Command 870[000C], DORCLS, causes the cooler door to move to the next closed position, if the door motor is on. Execution of DORCLS provides a move enable and a close direction signal to the door logic circuit.

Execution of DORCLS requires prior execution of DMTRON. The reciprocal is RST870. DORCLS is verified if TECHO = 0006.

Execution of any 870 command message requires that: (1) the TM be ON and (2) the selected command receiver (1 or 2) must match the powered RIU (A or B).

Command 871 message 0100, DFLARM, arms the cooler door fuse link firing circuit. Execution of DFLARM resets relay A8K5 (see Figure 14.6-15). Resetting A8K5 connects the pole (armature) of A8K3 to the reset coil of A8K7. If A8K3 has been reset, resetting A8K5 connects the combined command pulse bus to the rest coil of the fire relay, thus arming the fire circuitry. Execution of DFLARM requires that: (1) the TM be on, (2) macro-discrete command generator A be on,

(3) the powered command generator (prime or redundant) match the powered RIU (A or B), and (4) DFLENA be executed. The reciprocal to DFLARM is FLSAFE.

Command 872 message (4000), DMTRON, enables the cooler door motor drive and disengages the brake. Execution of DMTRON latches relay A9K1 (see Figure 14.6-14). Latching A9K1 connects the 33 volt bus to the motor brake release and motor drive circuits and connects the +8 volt logic bus to the 5 volt regulator that powers the door logic circuitry. If TM power is on, this command enables the door motor drive circuitry so that a door move enable command will cause the door to move in the direction selected. Execution of DMTRON requires (1) TM power to be On, (2) macro-discrete command generator B to be On, and (3) the command generator selected (prime or redundant) match the powered RIU (A or B). DMTROFF is the reciprocal command of DMTRON.

Command 872 message (2000), DMTROFF, disables the cooler door motor and engages the motor brake. Execution of DMTROFF latches relay A9K1 (see Figure 14.6-14). Latching A9K1 disconnects the 33-volt bus from the motor drive circuit and the brake release circuit and disconnects the 8-volt logic bus from the 5-volt regulator that provides motor logic power. Execution of DMTROFF requires that (1) TM power be ON, (2) macro-discrete command generator B be ON, and (3) the command generator selected (prime or redundant) interface with the powered RIU side (A or B). The reciprocal of DMTROFF is DMTRON.

Command 872 message (0040), DFLENA, enables the arming circuit for the door fuselink. Execution of DFLENA resets relay A8K3 (see Figure 14.6-15). Resetting A8K3 connects the combined command pulse bus to the reset coil and normally open contact of the arm relay (A8K5), thus permitting execution of the arm command. Execution of DFLENA requires that (1) TM power to be ON, (2) macro-discrete command generator B be ON, and (3) the selected command generator (prime or redundant) match the powered side (A or B) of the RIU. The reciprocal of DFENA is FLSAG.

Command 872 message (0010), DFLFIRE, turns on the door fuselink heater which softens the fusible link. Execution of DFLFIRE resets relay A8K7 (see Figure 14.6-15). Resetting A8K7 connects the Fusible Link bus (derived from IM bus A/B) to the fusible link heater control switches. With power applied, the switches turn on, applying bus voltage to the fusible link heater (15 ohms). As the temperature rises, the fusible link softens and the preloaded spring permanently moves the door to the full open position. The time required to soften the link is a function of applied voltage. The heater should be on for "TBD" seconds for proper operation. Execution of DFLFIRE requires that (1) the TM · on, (2) macro-discrete command generator B be on, (3) the selected com . generator (prime or redundant) interface with the powered side (A or B) of the RIU, and (4) DFLARM be executed. The reciprocal of DFLFIRE is FLSAFE.

Command 872 message 0001 (FLSAFE) disables fuse link operation. Execution of FLSAFE latches relays A8K3, A8K4, A8K54, A8K6, A8K7 and A8K8 (see Figure 14.6-7 and 14.6-18). Latching A8K7 and A3K8 disconnects the IM bus power from the switches that control the cooler door and calibration shutter fusible link heaters. Latching A8K5 and A8K6 disconnects the outputs of those relays from the latch coils of A8K7 and A8K8. Latching A8K3 and A8K4 disconnects the combined command pulse bus from the latching coils of relays A8K5 and A8K6. Execution of FLSAFE requires that (1) micro-discrete command generator B is on, and (2) the command message is routed via the RIU (A or B) that interfaces with the active command generator (see Paragraph 14.6.1.10). Execution of FLSAFE is verified if TSHRFZLK = 000, TDRFZLK = 000 and TM is On.

14.6.1.10 Serial Command Control

The Thematic Mapper utilizes three serial commands: 870, 871 and 872. Associated with each serial command is a 16-bit message. The TM provides a redundant command decoder for each serial command.

Command 870 is received, decoded, and processed into 16 discrete bilevel logic signals. Ten of these levels are used as control signals by the TM as noted below:

Message Bit #	State	Function
7	0	Inhibit Inchworm Motion
7	1	Enable Inchworm Motion
8	0	Inhibit Inchworm Contract
8	1	Enable Inchworm Contract
9	0	Inhibit Inchworm Extend
9	1	Enable Inchworm Extend
10	0	Disable Inchworm 3
10	1	Enable Inchworm 3
11	0	Disable Inchworm 2
11	1	Enable Inchworm 2
12	0	Disable Inchworm 1
12	1	Enable Inchworm 1
13	0	Inhibit Door Motion
13	1	Enable Door Motion
14	0	Door Direction Open
14	1	Door Direction Close
15	0	Disable A Midscan
15	1	Enable A Midscan
16	0	Disable B Midscan
16	1	Enable B Midscan

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There are two serial command receiver/decoders associated with command 870. Serial Command Receiver 1 (SCR #1) interfaces exclusively with RIU 8A. Serial command receiver 2 (SCR #2) interfaces exclusively with RIU 8B. One serial command receiver is on whenever the TM is on. The active command receiver is selected by discrete command.

Command 871 is received, decoded and processed by Macro-discrete Command Generator A (MDCG-A). Only sixteen of the possible messages represent valid commands. These 16 are are listed in the following table.

871 Command Message (HEX)	Command Function
8000	Enable SMA +Z Heater
4000	SMA +Z Heater Controller Off
2000	Enable SMA -Z Heater
1000	SMA -Z Heater Controller Off
0800	Enable Intermediate Stage Outgas Heater
0400	Intermediate Stage Controller On
0200	Intermediate Stage Controller Off
0100	Cooler Door Fusible Link Arm
0080	Shutter Fusible Link Arm
0040	Select Scan Line Corrector 1
0020	Select Scan Line Corrector 2
0010	Scan Line Corrector Off
0008	Lamp Sequencer On
0004	Lamp Sequencer Off
0002	Inchworm On
0001	Inchworm Off

Each valid decoded command produces a +28 volt pulse on the combined command pulse bus and a unique switch closure to ground, similar to a RIU discrete command but of longer duration. The primary MDCG-A is interfaced exclusively to RIU 8A, while MDCG-B is exclusively interfaced to RIU 8B. Therefore MDCG-A must be selected based upon which RIU side is powered. MDCG´s can be on or off and are controlled by three discrete commands.

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Command 872 is received, decoded, and processed by Macro-Discrete Command Generator B (MDCG-B). MDCG-B is identical in design to MDCG-A. The commands associated with MDCG-B are shown below. MDCG-B is also controlled by three commands.

872 Command Message (HEX)	Command Function
8000	Cold Stage Telemetry off
4000	Cooler Door Motor On
2000	Cooler Door Motor Off
1000	Baffle Heater Controller On
0800	Baffle Heater Backup On
0400	Baffle Heater Off
0200	Cold Stage Outgas Heater Enable
0100	Cold Stage Heater Controller On
0080	Cold Stage Heater Off
0040	Cooler Door Fuselink Enable
0020	LVDT On
0010	Cooler Door Fuselink Fire
0008	Shutter Fuselink Enable
0004	LVDT Off
0002	Shutter Fuselink Fire
0001	Fuselinks Safe

The commands controlling serial magnitude command receivers and decoders are:

	Command	
Number	Acronym	Name
726	SELPACG	Select Prime MDCG-A
760	SELRACG	Select Redundant MDCG-A
762	SCR1SEL	Select SCR #1
821	SELPBCG	Select Prime MDCG-B
827	MCGOFF	MDCG's Off
829	SCR2SEL	Select SCR #2
843	SELRBCG	Select Redundant MDCG-B

Command 726 (SELPACG) turns on Macro-discrete Command Generator A prime and turns off MDCG-A redundant. Execution of SELPACG resets relays A14K1, A14K2 and

latches relays A13K3 and A14K4 (see Figure 14.6-15). Resetting A14K1 connects the CDVU +9 volt bus to the 5 volt regulator that powers the interface and decoding circuits of MDCG-A prime and enables (grounds) the decoder. Resetting A14K2 connects the +33 volt bus to the pulse generator circuit and connects the MDCG-A Prime on telemetry to +5 volts. Latching A14K3 disconnects the CDVU +9 volt bus from the 5 volt regulator that powers the redundant MDCG-A interface and decoding circuits, and disables the redundant decode by disconnecting its return. Latching A14K4 disconnects the +33 volt bus from the redundant pulse generator and grounds (sets to zero) the redundant MDCG-A ON/OFF telemetry. The reciprocal command to SELPACG is SELRACG. Verification of SELPACG execution requires TM power to be ON. Proper execution of SELPACG will turn off the redundant MDCG-A and turn or the prime MDCG-A. This condition is sensed by the telemetry function TMDCGSEL (see Paragraph 14.7.2.23). Hence SELPACG is verified if the state of TMDCGSEL is A Prime, A Prime, B Redundant, or both Prime (TMDCGSEL = 10**), where * = 1 or Ø.

Command 760, SELRACG, turns on the redundant Macro-Discrete Command Geneator (MDCG) A and turns off the primary MDCG-A. Execution of SELRACG latches relays A14K1 and K2 and resets relays A14K3 and K4 (see Figuire 14.6-16). Latching relay A14K1 disconnects the CDVU +9 volt bus and the enable (ground) signal from the primary MDCG-A interfacae and decoding circuits. Latching A14K2 disconnects the +33 volt bus from the pulse generator circuit and grounds (sets to zero) the MDCG-A primary status telemetry. Resetting A14K3 connects the CDVU +9 volt bus to 5 volt regulator which powers the redundant MDCG-A interface and decoding circuits, and grounds (enables) the command decoder. Resetting A14K4 connects the +33 volt bus to the pulse generator and connects the redundant MDCG-A status telemetry to +5 volts. SELPACG is the reciprocal command of SELRACG. Verification of SELRACG requires that TM power be on. Verification consists of determining that the redundant MDCG-A is ON and that the primary MDCG-A is OFF. This condition is satisfied by TMDCGSEL = 01** (see Paragraph 14.7.2.23).

Command 762, SCR1SEL, turns on serial command receiver (SCR) number 1 and turns off SCR number 2. Execution of SCR1SEL resets relays A10K1 and A10K2 (see Figure 14.6-17). Resetting A10K1 disables SCR2 command decoder and enables SCR1 command encoder by switching the ground and connecting the SCR #1 status telemetry to +5 volts. Resetting A10K2 disconnects the CDVU +9 volt bus from SCR #2 and connects it to SCR #1, +5 volt regulator. SCR2SEL is the reciprical command to SCR1SEL. Verification of SCR1SEL requires that TM power be on. Verification requires that SCR #1 be on. This condition is monitored by the telemetry functions TSCRSTAT (see Paragraph 14.7.2.4) and SCR1SEL is verified if TSCRSTAT = 1. or if an 870 command message is executed with RIU 8B powered.

Command 821, SELPBCG, turns on the primary Macro-Discrete Command Generator (MDCG) B. Execution of MDCG-B resets relays A14K5 and A14K6 and latches relays A14K7 and A14K8 (see Figure 14.6-16). Resetting A14K5 connects the CDVU +9 volt bus to the 5-volt regulator that powers the primary MDCG interface circuits and decoders, and grounds (enables) the primary command decoder. Resetting A14K6 connects the +33 volt bus to the primary command pulse generator and connects the primary MDCG-B telemetry to +5 volts (set to 1). Latching A14K7 disconnects the CDVU +9 volt bus from the 5 volt regulator that powers the redundant MDCG-B command decoder and interface circuits and disables (disconnects from ground) the command decoder. Latching A14K8 disconnects the +33 volt bus from the redundant pulse generator and grounds (sets to zero) the redundant MDCG-B status telemetry. The reciprocal command of SELPBCG is SELRBCG. Verification of SELPBCG requires that TM power be ON. Verification consists of determining that the Primary MDCG-B is on and that the Redundant MDCG is OFF. This condition is sensed by the telemetry function TMDCGSEL (see Paragraph 14.7.2.23), and satisfied if TMDCGSEL = **10.

Command 827, MCGOFF, turns off all macro-discrete command generators. Execution of MCGOFF latches relays A14K1 athrough A14K8 (see Figure 14.6-16). Latching A14K1 disconnects the CDVU +9 volt bus and decode enable signal (ground) from the primary MDCG-A. Latching A14K2 disconnects the +33 volt bus from the MDCG-A pulse generator and grounds the MDCG-A Primary Status Telemetry. Latching A14K3 and A14K4 performs the identical function for MDCG-A Redundant. Latching A14K5 and K6 and A14K7 and K8 performs identical operations at MDCG-B prime and MDCG-B Redundant respectively. MCGOFF has no direct reciprocal. Verification of MCGOFF requires that TM power be ON. Verification consists of determining that all command generators are off. This condition is sensed by the telemetry function TMDCGSEL (see Paragraph 14.7.2.23) and is satisfied if TMDCGSEL = 0000.

Command 829, SCR2SEL, turns on Serial Command Reciever (SCR) number 2 and turns off number 1. Execution of SCR2SEL latches relays A10K1 and A10K2 (see Figure 14.6-17). Latching relay A10K1 removes the ground (enable signal) from the SCR #1 command decoder, connects it to SCR #2 decoder and grounds (sets to zero) the SCR #1 status telemetry. Latching A10K2 disconnects the CDVU +9 volt bus from the regulator powering SCR #1 and connects it to the 5 volt regulator powering SCR #2. SCR1SEL is the reciprocal command to SCR2SEL. Verification of SCR2SEL requires TM power to be ON. SCR2SEL is verified if SCR #2 is ON, which can be inferred by monitoring the status of SCR #1. If SCR #1 is Off, SCR #2 should be ON (Normal operation). This status is monitored by the telemetry function TSCRSTAT (see Paragraph 14.7.2). SCR2SEL is conditionally verified if TSCRSTAT = 0. SCR2SEL is absolutely verified if a 870 command message is executed with RIU 8B powered.

Command 843, SELRBCG, turns on the redundant macro-discrete command generator B and turns off the primary MDCG-B. Execution of SELRCG latches relay A14K5 and K6 and resets relays A14K7 and K8 (see Figure 14.6.4-16). Latching A14K5 disconnects the CDVU +9 volt bus from the 5 volt regulator that powers the primary MDCG-B interface and decoding circuits and disconnect the ground (disables) from the decoding circuits. Latching A14K6 disconnects the +33 volt bus from the primary, MDCG-B pulse generator, and grounds (sets to zero) the Primary MDCG-B status telemetry. Resetting A14K7 connects the CDVU +9 volt bus to the 5 volt regulator that powers the redundant MDCG-B interface and decoding circuits and connects the decoder to ground (the enable signal). Resetting relay A14K8 connects the +33 volt bus to the command pulse generator and +5 volt to the Redundant MDCG status telemetry. SELPBCG is the reciprocal to SELRBCG. Command verification requires that TM power be ON. Verification consists of determining that MDCG-B redundant is ON and Primary is OFF. This condition is sensed by the telemetry function TMCGSEL (Paragraph 14.7.2.23) and is satisfied if TMCGSEL = **01.

14.6.1.11 D.C. Restore Control

The Thematic Mapper utilizes DC restoration to eliminate amplifier drift. At the end of each shutter sweep, during the turn around interval, the reference level for each channel is re-established. For bands 1 through 5 and band 7, DC restoration is accomplished by setting the output to 2 1/2 ±1/2 counts during the interval when the field of view is blocked by the shutter. Band 6 DC restoration is accomplished by setting the output level to a value commensurate with shutter temperature. The shutter temperatures are sensed by thermistors on the calibration flag, backup flag and the aft optics frame. Selection of the Band 6 DC restore source is a function of shutter selection or by command. The DC restoration for band 6, only, can be selected by command.

The commands used to control DC restoration are:

Command Number	Command Acronym	Command Name
732	DMAGOFF	Frame DC Restore Select
742	DCRTMOFF	DC Restore & Telemetry Scaling Off
837	DCRON	DC Restore On

Command 732, DMAGOFF, selects the frame temperature derived Band 6 DC restore signal and de-energizes the radiative cooler door magnets. Execution of DMAGOFF, latches relay A8K1 and resets relays A16K10 and A16K11 (see Figure 14.6-17 and 14.6-18). Resetting A16K10 and A16K11 de-energizes the cooler door electro-magnetic latches (Paragraph 14.6.1.9). Latching relay A8K1 connects the dc restore signal derived from the aft optics frame temperature to the mux dc restore circuits, and disconnects the shutter temperature derived dc restore signal. If the TM is on, the Mux is On, and Telemetry Scaling is On, the Band 6 channels will be restored based upon frame temperature. DMAGOFF has no prerequisites and the commands CSHTRON and BUSHTRON are reciprocal in that they reset relay A8K1. Verification of DMAGOFF requires that power be removed from the door electro-magnets and frame dc restore be selected. These conditions are sensed by telemetry functions TDOOREM and TDCRSTAT. DMAGOFF is verified if TDOOREM = 0 and TDCRSTAT = *1 (* = 1 or 0).

Command 837, DCRON, turns on the normal Band 6 dc restore signal generators. Execution of DCRON resets relay A5K2 (see Figure 14.6-18). Resetting A5K2 connects the radiometer + and - 19 volt buses to the ±12 volt regulator that provides power to the cal and backup shutter temperature sensing and dc restore generation circuits (see Figure 14.6-6). DCRON has no pre-requisites and DCRTMOFF is its reciprocal. Execution of DCRON results in the following telemetry responses:

Function	State	Mode
TCALST	>2 cnts	-
TBUST	>2 cnts	-

Command 742, DCRTMOFF, turns off the Band 6 dc restoration and the telemetry scaling circuits. Execution of DCRTMOFF latches relays A5K2 and resets relay A8K2 (see Figure 14.6-18). Latching A5K2 disconnects the radiometer + and - 19 volt buses from the ±12 volt regulator that powers the dc restore generator and shutter temperature sensing circuits. Resetting A8K2 disconnects the radiometer + and - 19 volt buses from the ±12 volt regulator that power the telemetry scaling circuits. The telemetry scaling circuits consist of the telemetry monitors for the Blackbody Monitor, Silicon Focal Plane and Baffle Temperatures and the Frame dc restore signal generator. DCRTMOFF has no prerequisites and DCRON plus TLMSCLON represent a reciprocal set of commands. Execution of DCRTMOFF results in the following telemetry responses:

Function	State	Mode
TTLMSCAL	0	TLM Scale/DCR Off
TSIFPT	<2 cnts	
TBBT	<2 cnts	
TBAFFT	<2 cnts	
TCAST	<2 cnts	
TBUST	<2 cnts	

14.6.1.1.2 <u>Telemetry Scaling Control</u>

The telemetry scaling circuits monitor certain temperatures and produce telemetry compatible outputs. The circuits consist of ±6.4 volt reference supplies, six temperature telemetry conditioning circuits, and the band 6 dc restore signal generator. Three temperature conditioning circuits are unused and the other are silicon focal plane, blackbody and baffle temperature. The commands used to control the Telemetry scaling circuits are:

	Commands	
Number	Acronym	Name
742	DCRTMOFF	DC Restore/Telemetry Scaling
801	TLMSCLON	Telemetry Scaling On

Command 742, DCRTMOFF turns off the DC restore and telemetry scaling circuits. Execution of DCRTMOFF, latches relay A5K2 and resets relay A8K2 (see Figure 14.6-18). Latching A5K2 disconnects the radiometer + and -19 volt buses from the ±12 volt regulator that powers the DC restore circuits. Resetting A8K2 disconnects the radiometer + and - 19 volt buses from the ±12 volt regulator that powers the telemetry scaling circuits. DCRTMOFF has no prerequisites and commands TLMSCLON and DCRON together form the reciprocal. Execution of DCRTMOFF results in the following telemetry responses:

Function	State	Mode
TLMSCAL	0	TLM Scale/DCC Off
TSIFPT	<2 cnts	
TBBT	<2 cnts	
TBAFFT	<2 cnts	
TCALST	<2 cnts	
TBUST	<2 cnts	

Command 801 TLMSCLON turns on the telemetry scaling circuits. Execution of TLMSCLON latches relay A8K2 (see Figure 14.6-18). Latching A8K2 connects the radiometer + and - 19 volt buses to the ±12 volt regulator that powers the telemetry scaling circuits. TLMSCLON has no pre-requisite commands and DCRTMOFF is its reciprocal. Execution of TLMSCLON produces the following telemetry:

Function	State	Mode
TTLMCAL	1	TLM Scale/DCR TLM On
TS1FPT	>2 cnts	
TBBT	>2 cnts	
TBAFFT	>2 cnts	

14.6.1.13 Inchworm Control and Monitoring

The Thematic Mapper has two focal planes: an ambient focal plane and a cooled focal plane. The 64 detectors of bands 1 through 4 are mounted on the ambient or silicon focal plane. The 32 detectors of bands 5 and 7 and the 4 detectors of band 6 are mounted on the cooled focal plane. The ambient focal plane is fixed at the telescope focus. The cooled focal plane is imaged at the telescope focus by the relay optics. The spherical mirror of the relay optics is supported by inchworms at each of three equally spaced points around the mirror periphery. Motion of the inchworms provides for the alignment of the cooled detector arrays with respect to the ambient arrays and for focus adjustment of the cooled arrays. An indication of relative inchworm position during motion is provided by a linear variable differential transformer (LVDT) located on each inchworm. The inchworm and multiplexer power supplies share the 30 volt bus and the three inchworms share the same high voltage power supplies. To prevent overloading of the 30 volt bus or high voltage power supply, the multiplexer must be off during inchworm operation and only one inchworm shall be operated at a time. Inchworm monitoring and operation are controlled by two serial command 871 messages, two serial command 872 messages and eight the serial command 870 messages. The six bits of command 870 used in the eight messages are:

Bit #	Function
7	Move Command 1 = Move 0 = Don't Move
8	Extend Command 1 = Extend 0 = Don't Extend
9	Contract Command 1 = Contract 0 = Don't Contract
10	Inchworm 3 Command 1 = Enable 0 = Inhibit
11	Inchworm 2 Command 1 = Enable 0 = Inhibit
12	Inchworm 1 Command 1 = Enable 0 = Inhibit

Since entire 870 command messages must be sent, a number of inchworm command messages are defined in the following paragraphs. Their usage assumes that concurrent cooler door or midscan marker operations are prohibited. The inchworm control commands are:

Inchworm Commands

No.	Message (HEX)	Acronym	Name
870	0000	RST870	Reset 870
870	0200	IWCYCL	Inchworm Logic Cycle
870	0310	IW1EXT	Inchworm 1 Extend
870	0320	IW2EXT	Inchworm 2 Extend
870	0340	IW3EXT	Inchworm 3 Extend
870	0290	IW1CNT	Inchworm 1 Contract
870	02A0	IW2CNT	Inchworm 2 Contract
870	02C0	IW3CNT	Inchworm 3 Contract
871	0002	IWON	Inchworm Power On
871	0001	IWOFF	Inchworm Power Off
872	0020	LVDTON	LVDT Power On
872	0004	LVDTOFF	LVDT Power Off

Serial command 870 message $[0000]_{16}$, RST870, initializes all logic control signals to the inchworm drive circuits. Execution of RST870 executes 10 logic level commands: 6 inchworm commands, 2 cooler door commands and 2 midscan control commands. The six inchworm control commands disable the Move, Extend and Contract signals and inhibit inchworms 1, 2 and 3. The two cooler door commands inhibit door motion and set the door direction to OPEN. The Midscan commands disable (both A and B) the marker. RST870 is used to set the inchworm logic in a known state. Execution of RST870 requires that the command be executed by the RIU paired with the selected serial command receiver. There is no direct (sensible) reciprocal to the RST870 command. Verification of the receipt of RST870 can be accomplished, but not verification of execution. Receipt is verified if TECHO = $(00000)_{16}$.

Serial command 870 message [0200], IWCYCL, initiates an inchworm logic timing cycle. Execution of IWCYCL produces the same results as execution of RST870 except a logic one is presented to the MOVE circuit initiating a logic cycle. Logic operation requires inchworm power. RST870 is the reciprocal of IWCYCL. Execution of IWCYCL cannot be verified but receipt is verified if TECHO = $(0200)_{16}$.

Serial Command 870 message [0310], IW1EXTD, causes inchworm number 1 to extend one step. Execution of IW1EXTD provides an enable signal to inchworm 1 control logic , an extend enable signal to the logic decoder, and a move command to clock circuit. Assuming that inchworm power is on, one extension step will be executed by inchworm number 1 in approximately 2 seconds. RST870 is the reciprocal of IW1EXTD. Receipt of IW1EXTD is verified if TECHO = $(0310)_{16}$.

Execution of IW1EXTD may be discerned by noting a change in inchworm 1 position telemetry. The telemetry granuarity is approximately equal to the step size. Assuming a step is discernible, IW1EXTD is verified if:

TIW1POS @t+16 seconds $\geq$ TIW1POS @t

where t = time of command

Serial command 870 message [0320], IW2EXTD, causes inchworm number 2 to extend one step. Execution of IW2EXTD produces an enable signal at the inchworm 2 control logic, an extend enable signal to the decoding logic, and a move command to the clock circuit. Assuming inchworm power is on, one extension step will be executed by inchworm number 2, requiring approximately 2 seconds. RST870 is the reciprocal of IW2EXTD. Receipt of IW2EXTD is verified if TECHO = $(0320)_{16}$.

Execution of IW2EXTD may be verified by noting a change in inchworm 2 position telemetry. The telemetry granularity is approximately equal to the inchworm step size. Assuming a step is discernible, IW2EXTD is verified if:

TIW2POS @t+16 seconds $\geq$ TIW2POS @t

where t = time of command

Serial command 870 message [0340], IW3EXTD, causes inchworm number 3 to extend one step. Execution of IW3EXTD provides an enable signal to inchworm 3 central logic, an extend signal to the decoding logic, and a move command to the clock circuit. Assuming that inchworm power is on, one extension step will be executed by inchworm 3 requiring approximately 2 seconds. The reciprocal of IW3EXTD is RST 870. Receipt of IW3EXTD is verified if TECHO = $(0340)_{16}$.

Execution of IW3EXTD may be verified if a change in position telemetry can be discerned. The telemetry granularity and inchworm step size are approximately equal. Assuming a step is discernible, IW3EXTD is verified if:

TIW3POS @t+16 seconds $\geq$ TIW3POS @t

where t = time of command

Serial command 870 message [0290], IW1CONT, causes inchworm 1 to contract one step. Execution of IW1CONT provides an enable signal to inchworm control logic, a contract signal to the decoding logic, and a move command to the clock circuit. Assuming that inchworm power is on, a one step contraction will be executed by inchworm 1, requiring approximately 2 seconds. The reciprocal of IW1CONT is RST870. Receipt of IW1CONT is verified if TECHO $(0290)_{16}$.

Execution of IW1CONT may be verifiable if a change in position telemetry is discernible. The telemetry granularity and inchworm step size are approximately equal. Assuming a step is discernible IW1CONT is verified if:

TIW1POS @t+116 seconds $\geq$ TIW1POS @t

where t = time of command

Serial command 870 message [02A0], IW2CONT, causes a one step contraction by inchworm number 2. Execution of IW2CONT provides an enable signal to inchworm 2 control logic, a contract signal to the decoding logic and a move command to the clock circuit. Assuming that inchworm power is ON, a one step contraction in inchworm 2 will occur in approximately two seconds. The reciprocal of IW2CONT is RST870. Receipt of IW2CONT is verified if TECHO = $(02A0)_{16}$

Execution of IW2CONT may be verifiable if it causes a change in position telemetry. Telemetry granularity and step size are approximately equal IW2CONT is verified if:

TIW2POS @t+16 seconds

Serial command 870 message [002C0], IW3CONT, produces a one step contraction in Inchworm number 3. Execution of IW3CONT results in an enable signal to inchworm 3 control logic, a contract signal to the decoding logic and a move command to the clock circuit. Assuming that inchworm power is on, inchworm 3 will contract one step (~50 micro-inches). The reciprocal of IW3CONT is RST870. Receipt of IW2CONT is verified if TECHO = $(02C0)_{16}$.

Execution of IW3CONT may be verifiable if it produces a change in position telemetry. Since telemetry granularity is approximately equal to step size, verification may be feasible. IW3CONT is verified if:

TIW3POS @t+16 seconds $\geq$ TIW3POS @t

where t = time of command

Serial command 871 message [0002], IWON, applies power to the inchworm control and drive circuits. Execution of IWON resets relays A23K1 and A23K2 (see Figure 14.6-19). Reseting A23K1 connects the +8 volt bus to the 5 volt regulator that powers the inchworm logic and connects, through 4700 ohms, the +5 volt VU bus to the inchworm telemetry. Resetting A23K2 connects the +30 volt mux bus to the inchworm high voltage power supplies. Execution of IWON requires proper selection of RIU and command generator A and requires that command generator A be ON. IWOFF is the reciprocal to IWON. Execution of IWON is verified if TIWSTAT = 1*.

Verification requires that the TM be ON.

Serial command 871 message [0001], IWOFF, turns off power to the inchworm logic and drive circuits. Execution of IWOFF latches relays A23K1 and A23K2 (see Figure 14.6-19). Latching relay A23K1 disconnects the +8 volt bus from the 5 volt regulator that powers the inchworm status telemetry. Latching relay A23K2 disconnects the +30 volt mux bus from the inchworm high voltage power supplies. Execution of IWOFF requires proper selection of RIU and TM command generator A sides. IWON is the reciprocal to IWOFF. Execution of IWOFF is verified if TM power is on and TIWSTAT = 0*.

Serial command 872 message [0020], LVDTON, turns on the inchworm position telemetry. Execution of LVDTON resets relay A9K3 (see Figure 14.6-19). Resetting A9K3 connects the radiometer + and - 19 volt buses to the $\pm$15 volt regulators that power the inchworm position monitor circuits. Execution of LVDTON requires proper selection of RIU 8 and TM command generator B sides and TM power on. LVDTOFF is the reciprocal of LVDTON. Execution of LVDTON produces the following telemetry responses:

Function	State	Mode
TIWSTAT	*1	Inchworm TLM ON or Inchworm ON
TIW1POS	>2 cnts	
TIW2POS	>2 cnts	
TIW3POS	>2 cnts	

* 1 or Ø

Serial command 872 message [0004], LVDTOFF, turns on the inchworm position telemetry. Execution of LVDTOFF latches relay A9K3 (see Figure 14.6-19). Latching A9K3 disconnects the + and - 19 volt radiometer buses from the $\pm$15 volt regulator that powers the position telemetry. Execution of LVDTOFF requires TM ON and proper selection of RIU 8 and TM command generator B sides. LVDTON is the reciprocal of LVDTOFF. The following telemetry responses are produced by LVDTOFF, assuming TM is on.

Function	State	Mode
TIWSTAT	*0	LVDT OFF
TIW1POS	<2 cnts	
TIW2POS	<2 cnts	
TIW3POS	<2 cnts	

* 1 or Ø

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14.6.1.14 Cooler Temperature Control

The TM radiative cooler is equipped with two sets of heaters which are capable of warming up the cooler and maintaining its temperature at 293^{o} Kelvin. The intermediate stage heater is capable of producing approximately 29 watts and is controlled by three commands. The cold stage heaters can produce approximately 42 watts and are controlled by four commands. The cooler control commands are:

Cooler Temperature Control Commands

Number	Acronym	Name
871[0200]	DISISTC	Disable IS Temp Controller
871[0400]	ENAISTC	Enable IS Temp Controller
871[0800]	ISOUTENA	Enable IS Outgas
872[0080]	DISCSHTR	Disable CS Heater
872[0100]	ENACSHTR	Enable CS Heater
872[0200]	CSOUTENA	Enable CS Outgas Mode
872[8000]	CSTLMOFF	CS Telemetry OFF

Serial command 871 message [0200], DISISTC, turns off the intermediate stage outgas heater. Execution of DISISTC resets relay A16K5 and latches relay A5K4 (see Figure 14.6-20). Resetting A16K5 disables the outgas heater by removing the enable (ground) signal. Latching A5K4 disconnects the + and - 19 volt radiometer buses from the ±12 volt regulator that powers the outgas controller. Execution of DISISTC requires that an RIU 8/Macro-Discrete Command Generator (MDCG)-A pair be powered. DISISTC has two reciprocal commands; ENAISTC and ISOUTENA. Verification of DISISTC requires that TM power be ON. The telemetry response is:

Function	State	Mode
TISCNTRL	00	IS CNTRL OFF
TISCT	$>171^{o}K$	
TISHT	$\geq 317^{o}K$	

Serial command 871 message [0400], ENAISTC, enables the intermediate stage temperature monitoring and control. Execution of ENAISTC resets relay A5K4 (see Figure 14.6-20). Resetting A5K4 connects the + and - 19 volt radiometers buses to the ±12 volt regulator that powers the temperature monitoring and control circuits. Execution of this command rquires that an RIU 8/MDCG-A pair be

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powered. DISISTC is the reciprocal of ENAISTC. Verification of ENAISTC requires that TM power be ON. Execution of ENAISTC produces the following telemetry response:

Function	State	Mode
TISCNTRL	10	IS CNTRL ON TLM*
	11	IS CNTRL O/G ON*
TISTC	$\leq$171	
TISTH	$\leq$300	

*either mode

Serial command 871 message [0800], ISOUTENA, enables the intermediate stage outgas heater. If the intermediate stage controller is on, the outgas heater will be powered upon execution of this command. Execution of ISOUTENA latches relay A16K5 (see Figure 14.6-20). Latching A16K5 enables the outgas heater by providing a ground to the control circuits. Execution of ISOUTENA requires that a RIU8 MDCG-A pair be powered. DISISTC is the reciprocal to ISOUTENA. Command verification requires that CDVU +9 volt power be available (TM ON). Execution of ISOUTENA produces the following telemetry response.

Function	State	Mode
TISCNTRL	*1	IS CNTRL O/G SEL or IS CNTRL O/G ON

* 1 or 0

Serial command 872 message [0080], DISCSHTR, disables the cold stage outgas heater. If the intermediate stage heater is on, the outgas heater will be powered upon execution of this command. Execution of DISCSHTR resets relay A16K4 and latches relay A4K10 (see Figure 14.6-21). Resetting A16K4 disconnects the outgas on (ground) signal from the temperature controller, and grounds the Cold Stage Power On/Off telemetry input (TM 108-51). Latching A4K10 connects the + and - 15 volt cold stage controller buses to the heater control circuits. If the TM is on and the cold stage heater enabled, this command turns off the outgas heater. Execution requires TM to be on and an RIU 8/MDCG-B pair powered. The reciprocal to DISCSHTR are commands ENACSHTR and CSOUTENA. Execution of this command is verified if TCSCNTLR = 100. Verification requires that TM and cold stage controller power be on.

Serial command 872 message [0100], ENACSHTR, turns on the cold stage temperature monitoring and control. Execution of ENACSHTR latches relay A4K9 and resets relay A4K10 (see Figure 14.6-21). Latching A4K9 connects the + and - 19 volt radiometer buses to the ±15 volt regulator that power the cold stage temperature monitoring circuits. Resetting A4K10 connects the ±15 volt cold stage buses to the cold stage heater control circuit. If the outgas mode is enabled the heaters will turn on. Execution of ENACSHTR requires TM power and that a RIU 8/MDCG-B pair be powered. The reciprocal of ENACHSHTR is CSTGTMOF and DISCSHTR. Verification of ENACSHTR requires that TM power be on. Execution of ENACSHTR produces the following telemetry response.

Function	State	Mode
TCSCNTLR	11*	CS CNTRL ENABLE or CS CNTRL O/G ON
TCSHTRI	>60 mA	
TCSCT	$\geq 127^{o}K$	"TBD" time delay
TCSHT	$\geq 293^{o}K$	"TBD" time delay

* 1 or 0

Serial command 872 message [0200], CSOUTENA, enables the cold stage outgas heater. If the cold stage controller is on, the command turns on the outgas heater. Execution of CSOUTENA resets relay A16K4 (see Figure 14.6-21). Resetting A16K4 enables the outgas heater by providing a ground and connects the outgas on telemetry out to +5 volts. Execution of CSOUTENA requires that the TM be on and a RIU 8/MDCG-B pair be powered. CSOUTENA is verified if TM power is on and TCSCNTLR = **1.

Serial command 872 message [8000], CSTLMOFF, turns off the cold stage telemetry and disables the controller. Execution of CSTLMOFF resets relay A4K9 (see Figure 14.6-21). Resetting A4K9 disconnects the + and - 19 volt radiometer buses from the ±15 volt regulator that powers the cold stage telemetry and controller. CSTLMOFF execution requires that a RIU 8/TM MDCG-B pair be powered. The reciprocal of CSTLMOFF is ENACSHTR. Verification of CSTGTMOF requires that TM be ON. Execution of CSTGTMOF produces the following telemetry responses.

Function	State	Mode
TCSCNTLR	00*	CS CNTRL OFF or CS CNTRL O/G ENA
TCSHTRI	$\leq$0 mAmps	
TCSCT	$\geq 127^{o}K$	TBD TIME DELAY
TCSHT	$\geq 293^{o}K$	TBD TIME DELAY

*don't care (1 or 0)

14.6.1.15 Scan Line corrector Control

The Thematic Mapper radiometer utilizes a bi-directional scanner. To produce contiguous sweeps a scan line corrector (SLC) is employed. The purpose of the SLC is to correct for the forward motion of the spacecraft by displacing the optical axis backwards along the ground track at the rate equal to the velocity of the subsatellite point. This is accomplished by rotating two parallel mirrors, tilted 45^{o} from the optical axis. The SLC consists of a mirror assembly, drive motor, redundant tachometer and drive electronics (see Figure 14.6-22). The scan line corrector is controlled by three commands.

	SLC Commands	
Number	Acronym	Name
871[0010]	SLCOFF	Scan Line Correctors Off
871[0020]	SLC2SEL	Select SLC 2
871[0040]	SLC1SEL	Select SLC 1

Serial command 871 message [0010], SLCOFF, turns off both scan line correctors. Execution of SLCOFF resets relays A1K3, A1K4, A2K3 and A2K4 (see Figure 14.6-22). Resetting A1K3 disconnects the + and - 19 volt radiometer buses from the $\pm$15 volt regulator that powers scan line corrector number 1. Resetting A1K4 disconnects the +8 volt logic bus from the +5 volt regulator that provides logic power to SLC 1. Resetting relays A2K3 and A2K4 disconnect the + and - 19 volt radiometer bus from the $\pm$15 regulator and the +8 volt logic bus from the +5 volt regulator that power SLC #2. Execution of SLCOFF requires proper selection of RIU 8 and TM macrodiscrete command generator A sides (A/prime or B/redundant). Commands SLC1SEL and SLC2SEL are the complements (reciprocals) of SLCOFF. Verification of SLCOFF requires that both scan line correctors be off. Assuming the TM is ON, the following telemetry responses will obtain if SLCOFF executes:

Function	State	Mode
TSLCSES	00	SLC OFF
TMSLC1I	≤0 Amps	
TMSLC2I	≤0 Amps	
TSL115V	≤-2.5 Volts	
TSL15VP	≤0 Volts	
TSL215VP	≤-2.5 Volts	
TSL25VP	0 VOlts	

Serial command 871 message [0020] SLC2SEL, turns off scan line corrector electronics 1 and turns on scan line corrector electronics 2. Execution of SLC2SEL resets relays A1K2, A1K3, A1K4 and latches relays A2K2, A2K3, and A2K4 (see Figure 14.6-22). Resetting A1K2 disconnects SLC 1 electronics from the SLC motor. Resetting A1K3 and A1K4 disconnects the + and - 19 volt radiometer buses and the 8 volt logic bus from SLC 1 electronics. Latching A2K2 connects the motor drive output of SLC 2 electronics to the SLC motor. Latching A2K3 connects the + and - 19 volt radiometer buses to the ±15 volt regulator that provides power to SLC 2 electronics. Latching relay A2K4 connects the +8 volt logic bus to the 5 volt regulator that provides logic power to SLC2 electronics. SLC2SEL should be used to turn on scan line corrector 2 and should not be executed if scan line corrector 1 is on. Execution of SLC2SEL requires proper selection of RIU 8 and TM macrodiscrete command generator (MDCG) A sides (A/prime or B/redundant) and that the MDCG be on. The reciprocal of SLC2SEL is SLCOFF. Execution of SLC2SEL is verified if scan line corrector 2 turns on. If SLC2 turns on the following telemetry responses occur.

Function	State	Mode
TSLCSEL	01	SLC 2 ON
TSLC1I	≤0.2 Amps	
TSLC2I	(TBD)	
TSL115V	≤-2.5 Volts	
TSL15VP	≤0 Volts	
TSL215V	±0.2 Volts	
TSL25VP	5 ±.4 Volts	

Serial command 871 message [0040], SLC1SEL, turns off scan line corrector 2 electronics and turns on scan line corrector 1 electronics. Execution of SLC1SEL resets relays A2K2, A2K3, A2K4 and latches relays A1K2, A1K3, and A1K4 (see Figure 14.6-22). Resetting relay A2K2 disconnects SLC 2 electronics from the SLC motor. Resetting A2K3 and A2K4 disconnect the + and - 19 volt radiometer buses and the +8 volt logic bus from SLC 2 electronics. Latching A1K2 connects the motor drive output of SLC 1 electronics to the SLC motor. Latching A1K3 connects the + and - 19 volt radiometer buses to the ±15 volt regulator which provides power to SLC 1. Latching A1K4 connects the 8 volt logic bus to the 5 volt regulator that provides logic power to SLC 1 electronics. SLC1SEL is used to turn on SLC 1 but should not be executed if SLC 2 electronics are on. Execution of SLC1SEL requires that the side of RIU 8 that is powered be matched to the side of Macrodiscrete Command generator A that is powered (A and Prime or B and Redundant). The reciprocal of SLC1SEL is SLCOFF. Execution of SLC1SEL is verified if scan line corrector electronics 1 turns on. If SLC 1 electronics are on the following telemetry should be observed.

Function	State	Mode
TSLCSEL	10	SLC 1 ON
TSLC1I	TBD	
TSLC2I	≤0 Amps	
TSL115V	±0.2 Volts	
TSL15VP	5 ±.4 Volts	
TSL215V	≤-2.5 Volts	
TSL25V	≤0.0 Volts	

14.6.1.16 Baffle Temperature Control

The central baffle of the TM telescope is temperature controlled to 26° Centigrade (C). The temperature is sensed by a thermistor located midway along the baffle length. In the normal mode when the baffle temperature decreases below 26°C the heater is turned on. The closed loop control can be bypassed and a constant voltage applied to the heater by command. The commands that control the baffle heater are:

Baffle Temperature Control Command Number	Acronym	Name
872[0400]	BFHTRDIS	Baffle Heater Disable
872[0800]	BFHTRBU	Baffle Heater Backup
872[1000]	BFHTRENA	Baffle Heater Enable

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Serial command 872 message [0400], BFHTRDIS, turns off the baffle heater controller and selects the temperature control mode. Execution of BFHTRDIS resets relays A8K10 and A8K11 (see Figure 14.6-23). Resetting A8K10 disconnects the + and - 19 volt radiometer buses from the $\pm$15 volt regulator that powers the temperature controller. Resetting A8K11 connects the baffle heater return to the temperature controller. Execution of BFHTRDIS requires that a RIU 8 and Macro-Discrete COmmand Generator (MDCG)-B pair (A and Prime or B and Redundant) be powered. BFHTRDIS has two partial complements: BFHTRENA which latchs A8K10 and BFHTRBU which latches A8K11. Verification of BFHTRDIS requires that the Baffle temperature controller be off. The telemetry response associated with baffle temperature controller off is:

	Baffle Controller Telemetry	
Function	State	Mode
TBAFFHTR	00	BAFF HTR OFF
TBAFHTRI	$\leq$0 mAmps	

Serial command 872 message [0800], BFHTRBU, selects the constant voltage mode of baffle heater operation. Execution of BFHTRBU latches relay A8K11 (see Figure 14.6-23). Latching A8K11 disconnects the heater return from the controller and connects it to ground through 20 ohms. If heater power is enabled the heater is constantly on dissipating approximately 4 watts. Execution of BFHTRBU requires that a RIU 8/MDCG-B pair be powered. BFHTRDIS is the complement of BFHTRBU. Verification of BFHTRBU requires that the TM be ON and the baffle heater be enabled (BAFF HTR ENA). The telemetry response is:

Function	Start	Mode
TBAFFHTR	11	BAFF HTR BU
TBAFHTRI	333 $\pm$33 Amps	

Serial command 872 message [1000], BFHTRENA, enables the baffle temperature controller. If the normal mode has been selected, the baffle heater will be operated in the temperature control mode. If the backup mode has been selected the heater will be operated in the constant voltage mode. Execution of BFHTRENA latches relay A8K10 (see Figure 14.6-23). Latching A8K10 connects the + and - 19 volt radiometer buses to the $\pm$15 volt regulator that powers the baffle temperature controller. Execution of BFHTRENA requires that a RIU 8/MDCG-B pair be powered. BFHTRDIS is the reciprocal of BFHTRENA. Verification of BFHTRENA

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that the TM be ON or in standby. If BFHTRENA is executed the telemetry response is:

Function	State	Mode
TBAFFHTR	1*	BAFF HTR NORM or BAFF HTR BU
TBAFHTRI	0 to 513 mAmps	

* don't care (1 or 0)

14.6.2 COMMAND SEQUENCES

Thematic Mapper command sequences can be categorized as configuration sequences, operational sequences, and contingency sequences.

14.6.2.1 Configuration Sequences

Configuration sequences are used to select various sets of redundant components. Three operating modes have been defined: primary, redundant and mixed.

14.6.2.1.1 Primary Configuration Sequence

The primary configuration sequence selects all TM components designated as "1" or "prime". The primary configuration sequence places the TM in the PRIMARY configuration. The primary configuration sequence is:

CMD #	S/S	ACRONYM
634	PDU	ENATMA
601	PDU	ENSMAHTR
610	PDU	EXSBYHTR
470[1476]	SCCU	TMHAEN
470[3436]	SCCU	TMHBEN
642	TM	PS1OFF
615	TM	PS2OFF
839	TM	SHTROFF
827	TM	MCGOFF
714	TM	LP1OFF
734	TM	LP2OFF
738	TM	LP3OFF
706	TM	CSHTRON
708	TM	LP1ON

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710	TM	CFPAON
712	TM	LP2ON
716	TM	BBHTRENA
718	TM	BD1ON
728	TM	BD3ON
736	TM	THSDENA
740	TM	LP3ON
754	TM	BD2ON
758	TM	BD4ON
801	TM	TLMSCLON
815	TM	BD7ON
819	TM	BD5ON
837	TM	DCRON
847	TM	BD6ON
823	TM	SMEOFF
756	TM	SCR1SEL
726	TM	SELPACG
821	TM	SELPBCG
750	TM	SAM1SEL
748	TM	SME1SEL
632	TM	PS1ON
648	TM	MUX1ON
870[0000]	TM	RST870
872[0001]	TM	FLSAFE
871[0010]	TM	SLCOFF
871[0040]	TM	SLCISEL
871[8000]	TM	PSMAENA
871[2000]	TM	NSMAENA
871[0200]	TM	DISISTC
871[0400]	TM	ENAISTC
871[0008]	TM	SEQON
871[0001]	TM	IWOFF
872[0004]	TM	LVDTOFF
872[2000]	TM	DMTROFF
872[0400]	TM	BFHTRDIS
872[1000]	TM	BFHTRENA
872[0100]	TM	ENACSHTR
872[0080]	TM	DISCSHTR
827	TM	MCGOFF
642	TM	PS1OFF

14.6.2.1.2 Redundant Configuration Sequence

The redundant configuration sequence selects all TM components designated as "2" or "redundant". The redundant configuration sequence places the TM in the redundant configuration. The command sequence is:

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CMD #	S/S	ACRONYM
607	PDU	ENATMB
601	PDU	ENSMAHTR
610	PDU	EXSBYHTR
470[1476]	SCCU	TMHAEN
470[3436]	SCCU	TMHBEN
642	TM	PS1OFF
615	TM	PS2OFF
839	TM	SHTROFF
827	TM	MCGOFF
714	TM	LP1OFF
734	TM	LP2OFF
738	TM	LP3OFF
706	TM	CSHTRON
708	TM	LP1ON
710	TM	CFPAON
712	TM	LP2ON
716	TM	BBHTRENA
718	TM	BD1ON
728	TM	BD3ON
736	TM	THSDNENA
740	TM	LP3ON
754	TM	BD2ON
758	TM	BD4ON
801	TM	TLMSCLON
815	TM	BD7ON
819	TM	BD5ON
837	TM	DCRON
847	TM	BD6ON
823	TM	SMEOFF
829	TM	SCR2SEL
760	TM	SELRACG
843	TM	SELRBCG
831	TM	SAM2SEL
704	TM	SME2SEL
605	TM	PS2ON
621	TM	MUX2ON
870[0000]	TM	RST870
872[0001]	TM	FLSAFE
871[0010]	TM	SLCOFF
871[0020]	TM	SLC2SEL
871[8000]	TM	PSMAENA
871[2000]	TM	NSMAENA
871[0200]	TM	DISISTC
871[0400]	TM	ENAISTC
871[0008]	TM	SEQON
871[0001]	TM	IWOFF

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872[0004]	TM	LVDTOFF
872[2000]	TM	DMTROFF
872[0400]	TM	BFHTRDIS
872[1000]	TM	BFHTRENA
872[0100]	TM	ENACSHTR
872[0080]	TM	DISCSHTR
827	TM	MCGOFF
615	TM	PS2OFF

14.6.2.1.3 Mixed Configuration Sequences

Mixed configurations are comprised of any combination of prime (1) and redundant (2) components. Mixed configurations are obtained by starting with the prime or redundant configuration and selecting the desired "other" component. The selections are:

COMPONENT	PRIMARY SELECTION		REDUNDANT SELECTION	
Power Supply	631	MUX2OFF	658	MUX1OFF
	615	PS2OFF	642	PS1OFF
	632	PS1ON	605	PS2ON
	648	MUX1ON	621	MUX2ON
Command Generators*	827	MCGOFF	827	MCGOFF
	726	SELPACG	760	SELRACG
	762	SCR1SEL	829	SCR2SEL
	821	SELPBCG	843	SELRBCG
Scan Mirror Electronics	823	SMEOFF	823	SMEOFF
	748	SEM1SEL	704	SME2SEL
Scan Angle Monitor*	750	SAM1SEL	881	SAM2SEL
Scan Line Corrector*	871[0040]	SLC1SEL	871[0020]	SCC2SEL

*Notes:

1. Since the primary and redundant command receivers are paired to the side A and B of RIU 8 all three must be switched as must the RIU.

2. SAM 1 and 2 are interfaced to SME1 and 2 respectively (i.e., SAM1 controls SME1 and SAM2 controls SME2).

3. The TM must be on to execute serial magnitude commands.

14.6.2.2 Operational Sequences

Operational sequences are those required to place the TM in an operating mode.

14.6.2.2.1 Launch Mode Sequence

In the LAUNCH mode the TM is configured primary, is off and disabled, and the cooler door electro-magnets are energized. The sequences and commands required to place the TM in the LAUNCH mode are listed below.

CMD #	S/S	ACRONYM OR SEQUENCE
-	-	PRIMARY CONFIGURATION SEQUENCE
662	PDU	DISTM
638	PDU	DSFSLINK
645	PDU	TM19OFF
722	TM	DMAGON

14.6.2.2.2 Primary Turn On Sequence

The primary IMAGE mode consists of the TM in the prime configuration and in the IMAGE mode. The command sequence required to place the TM in the primary IMAGE mode from the primary STANDBY mode is listed below:

CMD #	S/S	ACRONYM
632	TM	PS1ON
	16 second delay	
645	PDU	TM19OFF

14.6.2.2.3 Redundant Turn On Sequence

This sequence transitions the TM from the redundant STANDBY mode to the redundant IMAGE mode. The redundant IMAGE mode consists of the TM configured redundantly and on in the IMAGE mode. The sequence is listed below:

CMD #	S/S	ACRONYM
605	TM	PS2ON
		16 second delay
645	PDU	TM19OFF

14.6.2.2.4 Standby Sequence

To transition from the IMAGE mode to the STANDBY mode the following sequence is required:

CMD #	S/S	ACRONYM
616	PDU	TM19ON
		16 second delay
642	TM	PS1OFF
615	TM	PS2OFF

14.6.2.2.5 Off Sequence

To transition from the IMAGE or STANDBY modes to the OFF mode the following command sequence is required.

CMD #	S/S	ACRONYM
642	TM	PS1OFF
615	TM	PS2OFF
645	PDU	TM19OFF

14.6.2.3 Contingency Sequences

Contingency sequences are used to change operational characteristics and cause performance changes.

14.6.2.3.1 Calibration Lamp Control Sequences

In the IMAGE modes, the calibration lamps operate in the automatic sequencing mode. In this mode, the radiance output of each lamp is actively controlled and the lamp is turned on and off automatically by the sequencer. Two contingency modes are available: manual sequence and constant current. If the sequencer fails, the lamps can be operated in the manual sequence mode. The following sequence operates the lamps in approximately the same manner as the automatic sequencer.

CMD #	S/S	ACRONYM	DELAY
871[0004]	TM	SEQ OFF	10 seconds
738	TM	LP1OFF	--
734	TM	LP2OFF	--
714	TM	LP3OFF	--

repeat the following when TM is ON:

CMD #	S/S	ACRONYM	DELAY
708	TM	LP1ON	3 seconds
712	TM	LP2ON	3 seconds
738	TM	LP1OFF	3 seconds
740	TM	LP3ON	3 seconds
708	TM	LP1ON	3 seconds
734	TM	LP2OFF	3 seconds
738	TM	LP1OFF	3 seconds
714	TM	LP3OFF	3 seconds

If the active feedback control fails, the lamps may be operated in the override mode. Since the sequencer uses the radiance controller to turn lamps off, the lamps must be sequenced manually. The override mode command sequence is listed below:

CMD #	S/S	ACRONYM
871[0004]	TM	SEQOFF
738	TM	LP1OFF
734	TM	LP2OFF
714	TM	LP3OFF

Repeat the following when TM is ON:

CMD #	S/S	ACRONYM	DELAY
708	TM	LP1ON	--
809	TM	LP1ORON	3 seconds
712	TM	LP2ON	--
807	TM	LP2ORON	3 seconds
738	TM	LP1OFF	3 seconds
740	TM	LP3ON	--
833	TM	LP3ORON	3 seconds
708	TM	LP1ON	--
809	TM	LP1ORON	3 seconds
734	TM	LP2OFF	3 seconds
738	TM	LP1OFF	3 seconds
714	TM	LP3OFF	3 seconds

14.6.2.3.2 CFPA Temperature Control Sequences

The cold focal plane assembly can be controlled at one of three selectable temperatures, assuming its uncontrolled temperature is sufficiently cold. If the CFPA heater fails, the temperature can be controlled using a backup mode of the cold stage heater. The command sequences associated with CFPA control modes are listed below.

The command sequence to select temperature control point T2 (95° Kelvin) is:

CMD #	S/S	ACRONYM
710	TM	CFPAONT1
805	TM	CFPA2SEL

The command sequence to select temperature control point T3 (105° Kelvin) is:

CMD #	S/S	ACRONYM
710	TM	CFPAONT1
811	TM	CFPA3SEL

The command sequence to select temperature control point T1 (90° Kelvin) is:

CMD #	S/S	ACRONYM
710	TM	CFPAONT1

The command sequence to select temperature monitor mode is:

CMD #	S/S	ACRONYM
710	TM	CFPAONT1
744	TM	CFPAOFF

14.6.2.3.3 Blackbody Temperature Control

The band 6 calibration blackbody can be controlled at any of three set points. If the temperature control thermister fails, the circuit can be operated in the constant power mode. The command sequences associated with blackbody control are listed below.

The sequence to select control temperature T1 (24°C) is:

CMD #	S/S	ACRONYM
746	TM	BBHTRDIS
716	TM	BBHTRENA

The sequence to select control temperature T2 (30°C) is:

CMD #	S/S	ACRONYM
746	TM	BBHTRDIS
716	TM	BBHTRENA
813	TM	BBT2SEL

The sequence required to select control temperature T3 (35°C) is:

CMD #	S/S	ACRONYM
746	TM	BBHTRDIS
716	TM	BBHTRENA
835	TM	BBT3SEL

The sequence required to select the constant power mode is:

CMD #	S/S	ACRONYM
716	TM	BBHTRENA
817	TM	BBBKUPON

14.6.2.3.4 CFPA Refocus and Re-Alignment Sequences

The cold focal plane can be re-aligned and re-focused relative to the prime focal plane by command. Re alignment and re-focusing are accomplished by moving the spherical mirror of the relay lens set. The spherical mirror can be tilted (alignment) or translated (focus) using three devices called inchworms. Each inchworm can be extended or contracted one step (~50 micro inches) at a time the command sequences are:

Inchworm Move Sequence (Primary)

CMD #	S/S	ACRONYM
658	TM	MUX1OFF

CMD #	S/S	ACRONYM	DELAY	
726	TM	SELPACG	--	
821	TM	SELPBCG	--	
872[0020]	TM	LVDTON	10 seconds	
871[0002]	TM	IWON	10 seconds	
870[0200]	TM	IWCYCLE	10 seconds	
870[0000]	TM	RST870	--	
*	TM	*	16 seconds	repeat for
870[0000]	TM	RST870	--	required #
871[0001]	TM	IWOFF	10 seconds	of steps
872[0004]	TM	LVDTOFF	10 seconds	
827	TM	MCGOFF	--	
648	TM	MUX1ON	--	

Inchworm Move Sequence (Redundant)

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CMD #	S/S	ACRONYM	DELAY	
631	TM	MUX2OFF	--	
760	TM	SELRACG	--	
843	TM	SELRECG	--	
872[0020]	TM	LVDTON	10 seconds	
871[0002]	TM	IWON	10 seconds	
870[0200]	TM	IWCYCLE	--	
870[0000]	TM	RST870	--	
*	TM	*		repeat for
870[0000]	TM	RST870	--	required #
871[0001]	TM	IWOFF	10 seconds	of steps
872[0004]	TM	LVDTOFF	10 seconds	
827	TM	MCGOFF	--	
648	TM	MUX2ON	--	

*See Table 14.6-5 for appropriate command

Table 14.6-5. Inchworm Commands

INCHWORM MOTION	CMD #	ACRONYM
EXTEND #1	870[0310]	IW1EXT
EXTEND #2	870[0320]	IW2EXT
EXTEND #3	870[0340]	IW3EXT
CONTRACT #1	870[0290]	IW1CNT
CONTRACT #2	870[02A0]	IW2CNT
CONTRACT #3	870[0200]	IW3CNT

14.6.2.3.5 Radiative Cooler Thermal Control

The radiative cooler provides (in space) the operating temperature for the cold focal plane. The two stage cooler can be temperature controlled at elevated temperatures by the cold stage and intermediate stage temperature controllers. In the outgas mode the cooler is maintained at 20°C. The cold stage temperature controller may also be used as a backup method of controlling the CFPA temperature. The command sequences are:

Outgas mode sequence:

CMD #	ACRONYM	DELAY
827	MCGOFF	--
*	*	--
*	*	--
872[0100]	ENACSHTR	10 seconds
872[0200]	ENACSHTR	10 seconds
871[0400]	ENAISTC	10 seconds

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871[0800]	ISOUTENA	10 seconds
827	MCGOFF	--

CMD #	ACRONYM	DELAY
827	MCGOFF	--
**	**	--
872[0080]	DISCSHTR	10 seconds
872[0100]	ENACSHTR	10 seconds
827	MCGOFF	--

OFF sequence:

CMD #	ACRONYM	DELAY
827	MCGOFF	--
*	*	--
*	*	--
871[0200]	DISISTC	10 seconds
872[0080]	DISCSHTR	10 seconds
872[8000]	CSTGTMOF	10 seconds
827	MCGOFF	--

Telemetry sequence:

CMD #	ACRONYM	DELAY
827	MCGOFF	--
*	*	--
*	*	--
871[0200]	DISISTC	10 seconds
871[0400]	ENAISTC	10 seconds
872[0100]	ENACSHTR	10 seconds
872[0080]	DISCSHTR	10 seconds
827	MCGOFF	--

* Commands 726, SELPACG, and 821, SELPBCG or, 760, SECRACG and 843 SELRBCG dependent upon configuration - Prime or Redundant

** 821, SELPBCG if configuration is Prime, 843, SELRBCG, if Redundant

14.6.2.3.6 Baffle Temperature Control Sequences

The temperature of the telescope baffles is maintained at 26°C. The baffle controller has two active operating modes: temperature control and constant power. The command sequences associated with baffle temperature control are:

Temperature control mode sequence:

PRIMARY CMD #	ACRONYM	REDUNDANT CMD #	ACRONYM
827	MCGOFF	827	MCGOFF
821	SELPBCG	843	SELRBCG
872[040]*	BFHTRDIS	872[0400]	BFHTRDIS*
872[1000]*	BFHTRENA	872[1000]	BFHTRENA*
827	MCGOFF	827	MCGOFF

Constant power mode:

PRIMARY CMD #	ACRONYM	REDUNDANT CMD #	ACRONYM
827	MCGOFF	827	MCGOFF
821	SELPBCG	843	SLLRBCG
872[1000]*	BFHTRENA	872[1000]*	BFHTRENA
872[0800]*	BFHTRBU	872[0800]*	BFHTRBU
827	MCGOFF	827	MCGOFF

*10 second delay following command

14.6.2.3.7 Mid Scan Marker Sequence

A marker can be inserted in the data at the point of mid-scan by command. The marker replaces video data of bands 1 through 5 and 7 and consists of 48 words of white (level 255) followed by 48 words of black (level 0). The command sequences required for mid-scan markers are:

Mid-scan on sequence:

CMD #	ACRONYM
*	*
870[0003]	MIDSCN

Mid-scan off sequence:

CMD #	ACRONYM
870[0000]	RST870

* 762 SCR1SEL for Primary configuration, 829 SCR2SEL for Redundant configuration

14.6.2.3.8 Scan Mirror Temperature Control Sequences

The scan mirror assembly can be temperature controlled at 20°C using two 25 ohm heaters and the SMA temperature controllers. The required command sequences are:

SMA Temperature Control Enable:

CMD #	S/S	ACRONYM	DELAY
601	PDU	ENSMAHTR	--
827	TM*	MCGOFF	--
*	TM	*	--
871[8000]	TM	PSMAENA	10 seconds
871[2000]	TM	NSMAENA	10 seconds
827	TM	MCGOFF	--

SMA Temperature Control Disable:

CMD #	S/S	ACRONYM	DELAY
827	TM	MCGOFF	--
*	TM	*	--
871[4000]	TM	PSMADIS	10 seconds
871[1000]	TM	NSMADIS	10 seconds
827	TM	MCGOFF	--
636	PDU	DSSMAHTR	--

* Cmd 726, SELPACG, if configured Prime or 760, SELRACG, if Redundant

14.6.2.3.9 Shutter Control Sequences

The TM is equipped with a backup shutter which will provide the DC restore function of the calibration shutter but not the calibration function. In order to use the backup shutter, the cal shutter must be removed from the optical path. THIS OPERATION IS IRREVERSIBLE. The backup shutter can be functionally tested in a reversible manner.

Backup Shutter Test Sequence:

CMD #	ACRONYM
839	SHTROFF
738	LP1OFF
714	LP3OFF
734	LP2OFF
746	BBHTRDIS
827	MCGOFF
*	*
871[0004]**	SEQOFF
827	MCGOFF
803	BUSHTRON

Calibration Shutter Turn On Sequence:

CMD #	ACRONYM
839	SHTROFF
708	LP1ON
712	LP2ON
716	BBHTRENA
740	LP3ON
827**	MCGOFF
*	*
871[0008]	SEQON
827	MCGOFF
706	CSHTRON

Backup Shutter Turn On Sequence:

CMD #	ACRONYM	
839	SHTROFF	
738	LP1OFF	
734	LP2OFF	
714	LP3OFF	
746	BBHTRDIS	
827	MCGOFF	
*	*	
***	***	
871[0004]*	SEQOFF	
872[0008]**	SFLENA	
871[0080]**	SFLARM	
872[0002]	SFLFIRE	3 minute delay

872[0001]**	FLSAFE
827	MCGOFF
803	BUSHTRON

* Cmd 726, SELPACG, if configured Prime or 760, SELRACG, if Redundant

** 10 second delay

*** Cmd 821, SELPB, if configured Prime or 843, SELRBCG if Redundant

14.6.2.3.10 Door Control Sequences

The TM radiative cooler door can be commanded to any of three positions: closed, outgas (a position about 3^{o} from closed), and open (a position about 90^{o} from closed). If the door latch (electro-magnet) is energized, it must be de-energized to permit the door to open. In the event of a motor or motor drive failure, the door can be moved to open position by activating the door fusible link. The door command sequences are:

Door Open Sequence: (moves door 1 position in the open direction)

CMD #	ACRONYM	DELAY	
827	MCGOFF	--	
*	*	--	
**	**	--	
872[4000]	DMTRON	10 seconds	
870[0008]	DOROPN	15 seconds	
870[0000]	RST870	--	***
872[2000]	DMTROFF	10 seconds	
827	MCGOFF	--	

Door Close Sequence:

CMD #	ACRONYM	DELAY	
827	MCGOFF	--	
*	*	--	
**	**	--	
872[4000]	DMTRON	10 seconds	
870[000C]	DCRCLS	15 seconds	
870[0000]	RST870	--	***
872[2000]	DMTROFF	10 seconds	
827	MCGOFF	--	

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Emergency Door Open Sequence:

CMD #	ACRONYM	DELAY
827	MCGOFF	--
*	*	--
****	****	--
872[0040]	DFLENA	10 seconds
871[0100]	DFLARM	10 seconds
872[0010]	DFLFIRE	3 minutes
872[0001]	FLSAFE	10 seconds
827	MCGOFF	

* 821 SELPBCG, if in Prime configuration or 843, SELRBCG, if Redundant

** 762 SCR1SEL if in Prime configuraiton or 829 SCR2SEL if Redundant

*** repeat if desired to mode to next open or closed position

**** 726 SELPACG if in Prime configuration or 760 SELRACG if in Redundant

14.6.2.2.6 Inertial Safehold Sequence

This command sequence should be transmitted as soon as command capability is established after entering the inertial safehold mode.

CMD #	ACRONYM	DELAY
634	ENATMA	--
642	PS1OFF	--
658	MUX1OFF	--
839	SHTROFF	--
823	SMEOFF	--
*	*	--
**	**	--
	PS1ON	--
872[4000]	DMTRON	10 seconds
870[0000]	DORCLS	15 seconds
870[0000]	RST870	--
872[2000]	DMTROFF	10 seconds
827	MCGOFF	--
616	TM19ON	--
642	PS1OFF	--

LSD-WPC-263

* 762, SCR1SEL, or 829, SCR2SEL based upon configuration Prime or Redundant

** 821, SELPBCC, or 843, SELRBCG, based upon Prime or Redundant S/C configuration

14.6.3 TM COMMAND CONSTRAINTS

The command constraints appear in Paragraph 14.4.2 but are repeated here for convenience.

14.6.3.1 Discrete to Serial Magnitude Command Timing

A discrete command shall not be directed to the TM within 32 miliseconds of a serial command message associated with serial magnitude command 871 or 872.

14.6.3.2 Serial Command Message Timing

Serial command messages associated with a unique TM serial command (871 or 872) shall be separated by a minimum of 10 seconds.

14.6.3.3 Serial Content Message Command

Serial command messages associated with commnads 871 and 872 shall contain no more than one (1) 1 (one).

14.6.3.4 Multiplexer Operation

The multiplexer shall not be commanded on if inchworm power is ON.

14.6.3.5 Multiplexer Turn-On

The multiplexer turn on commands (MUX1ON or MUX2ON) shall not be executed within 20 milliseconds of issuing a power supply on command (PS1ON or PS2ON).

14.6.3.6 Inchworm Operation

The inchworm power supply shall not be turned-on (IWON) if the multiplexer if on.

14.6.3.7 Calibration Shutter

Once the calibration shutter is powered off, power shall not be resupplied for at least 60 seconds to allow the slow start capacitor to discharge.

14.6.4 COMMAND FUNCTIONAL BLOCK DIAGRAMS

The figures refered to in Paragraph 14.6.1 appear on the following pages:

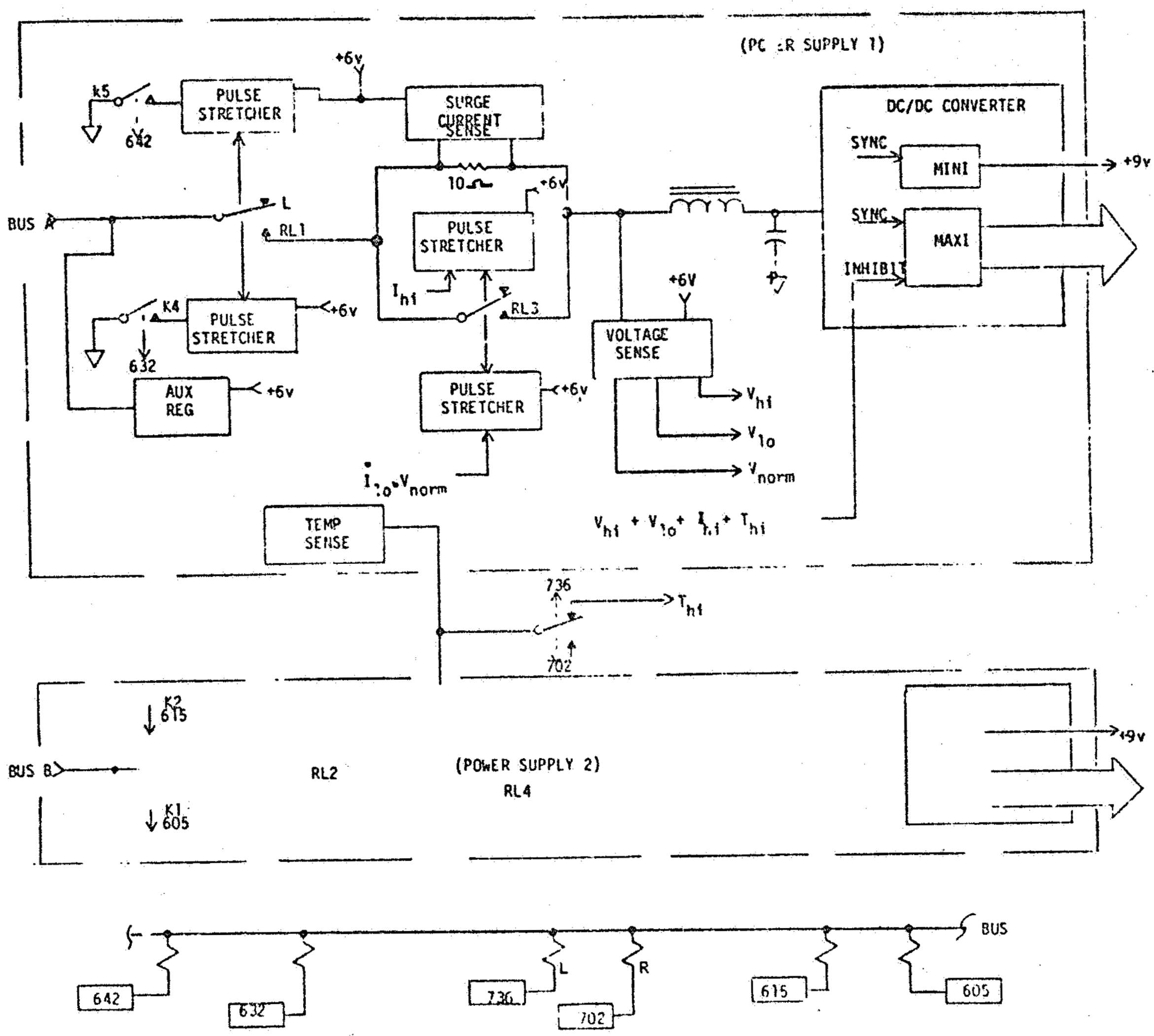
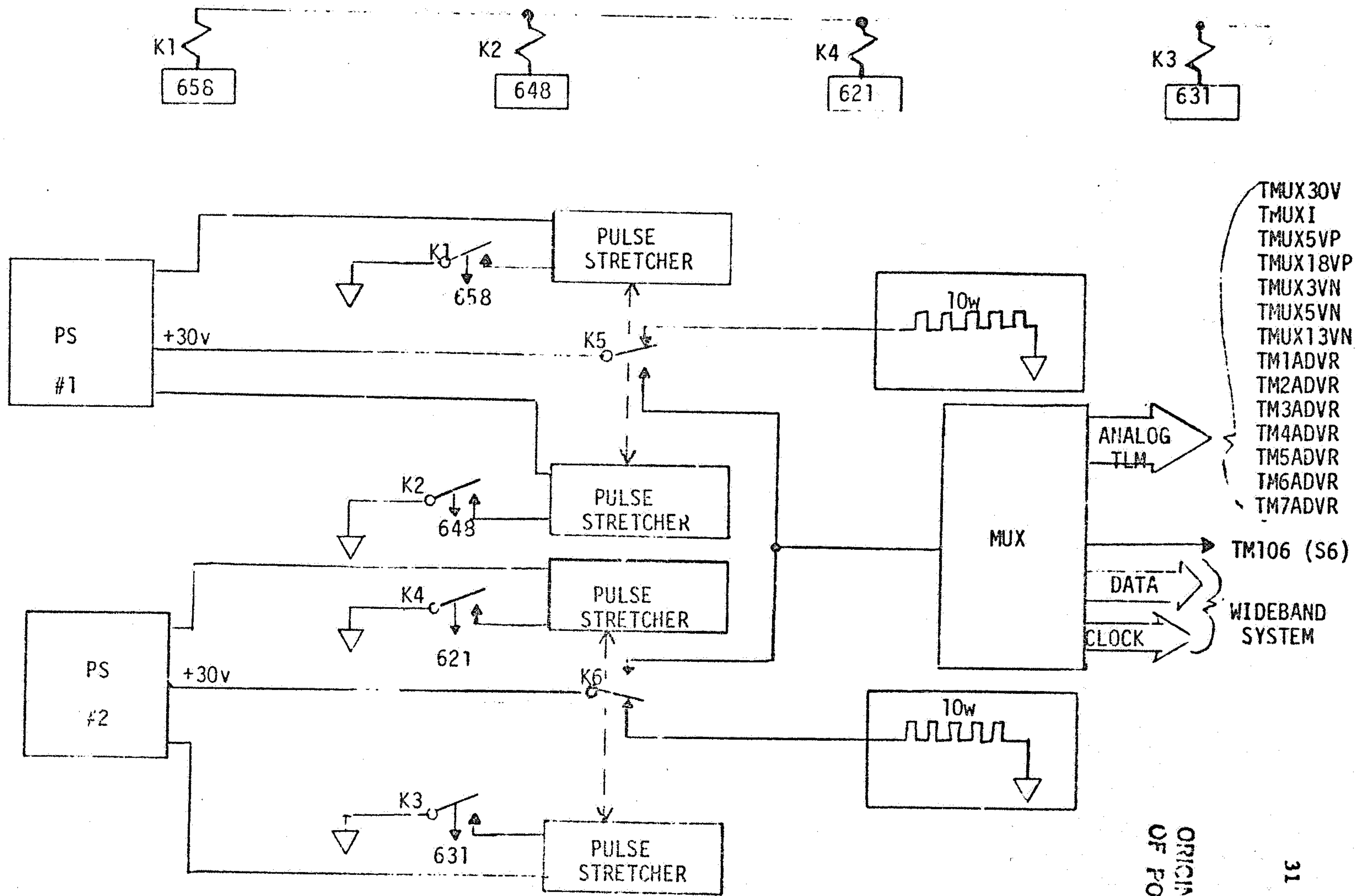


Figure 14.6-1. Power Supply Control .



NOTE: K5, K6 shown in Reset Position

Figure 14.6-2. MUX Power Control

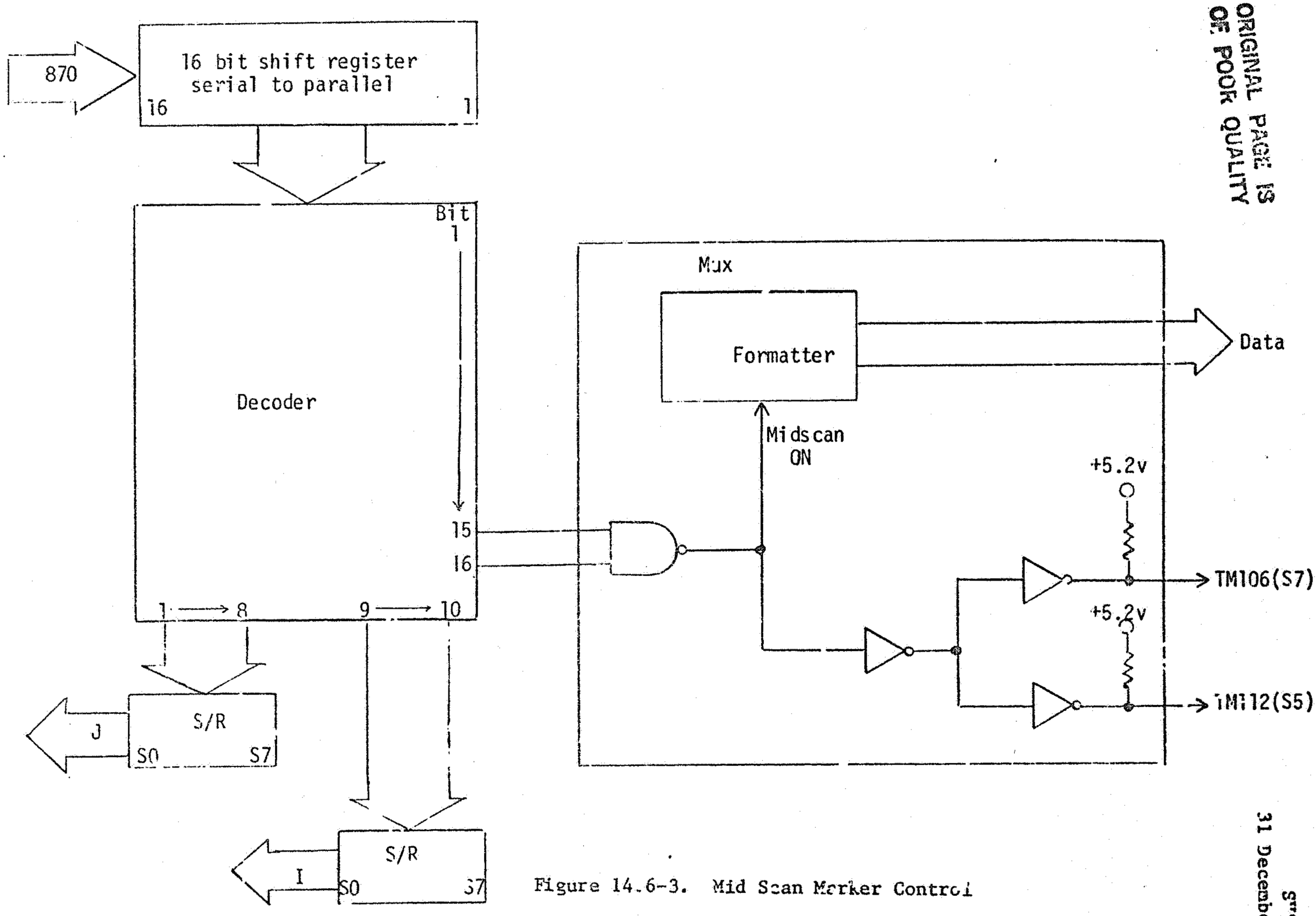


Figure 14.6-3. Mid Scan Marker Control

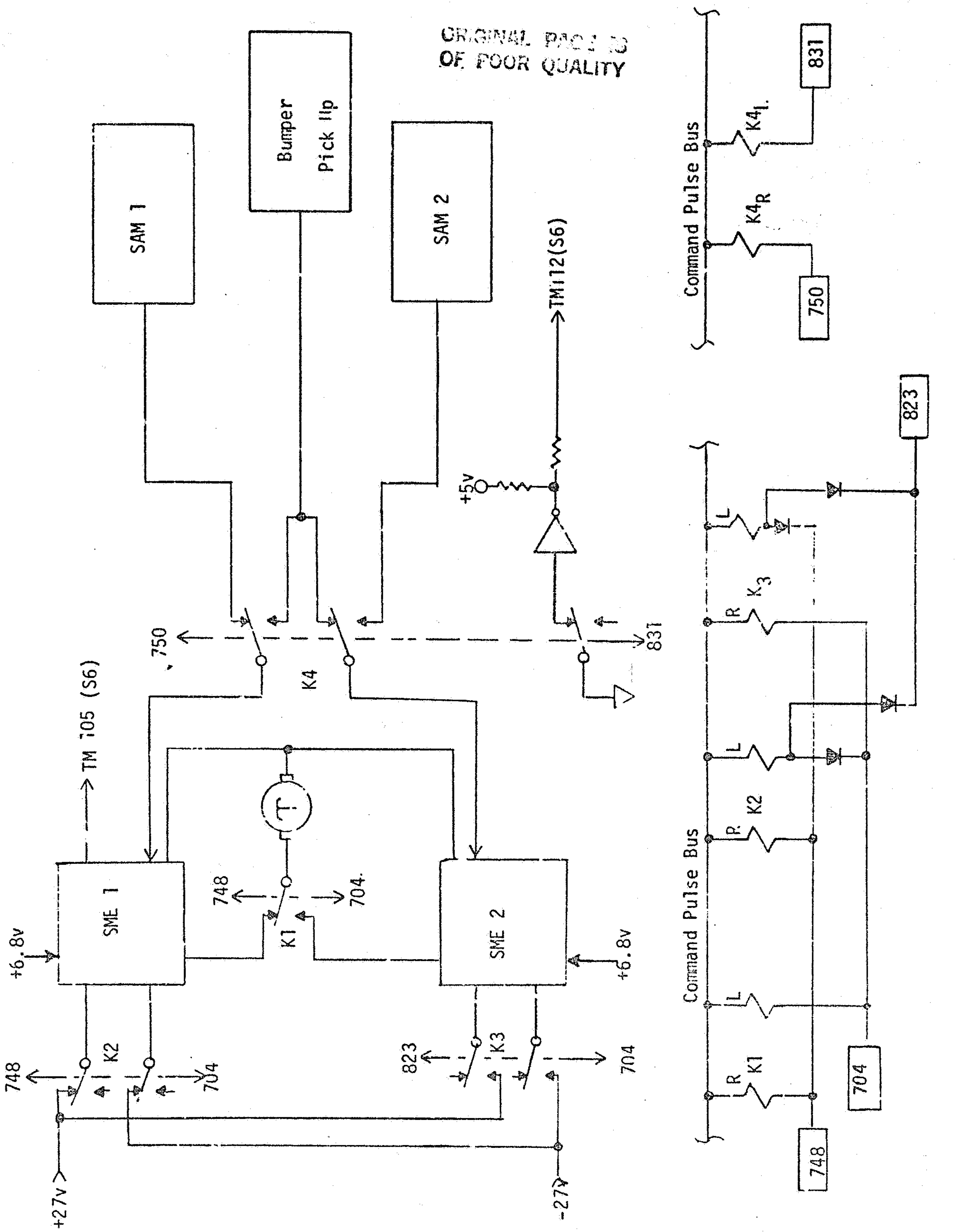


Figure 14.6-4. Scan Mirror Command Control

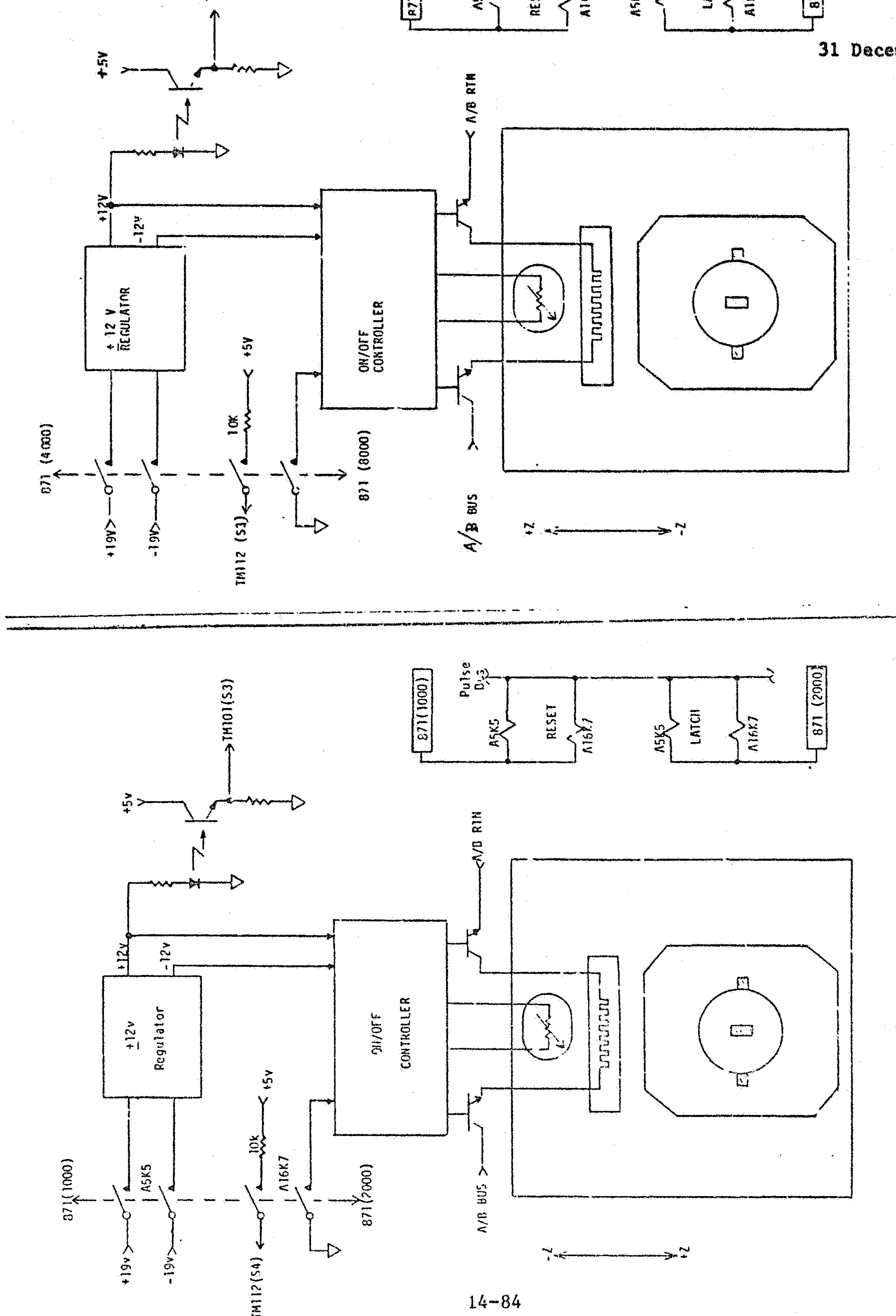


Figure 14.6-5. SMA Heater Control

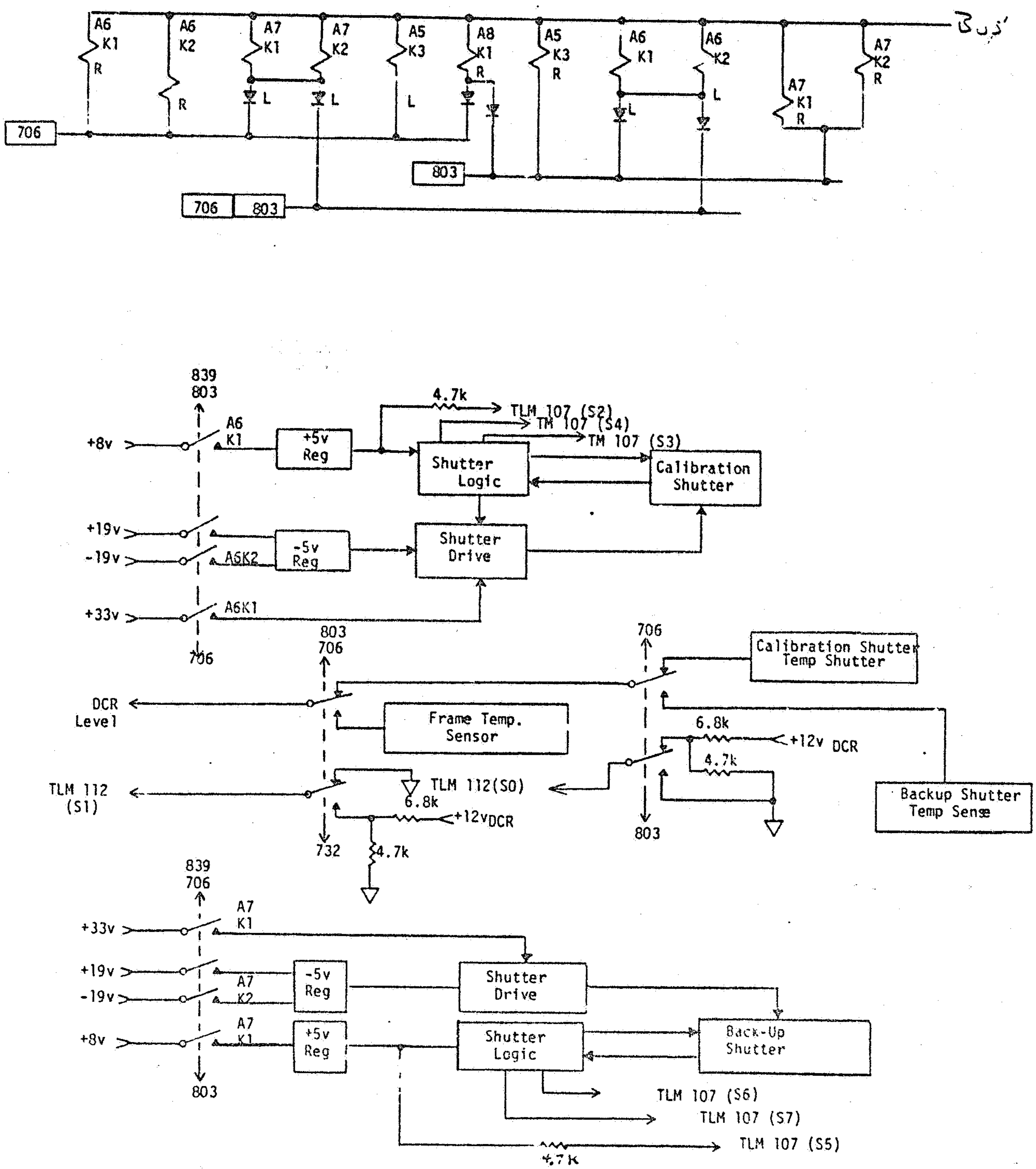


Figure 14.6-6. Shutter Control

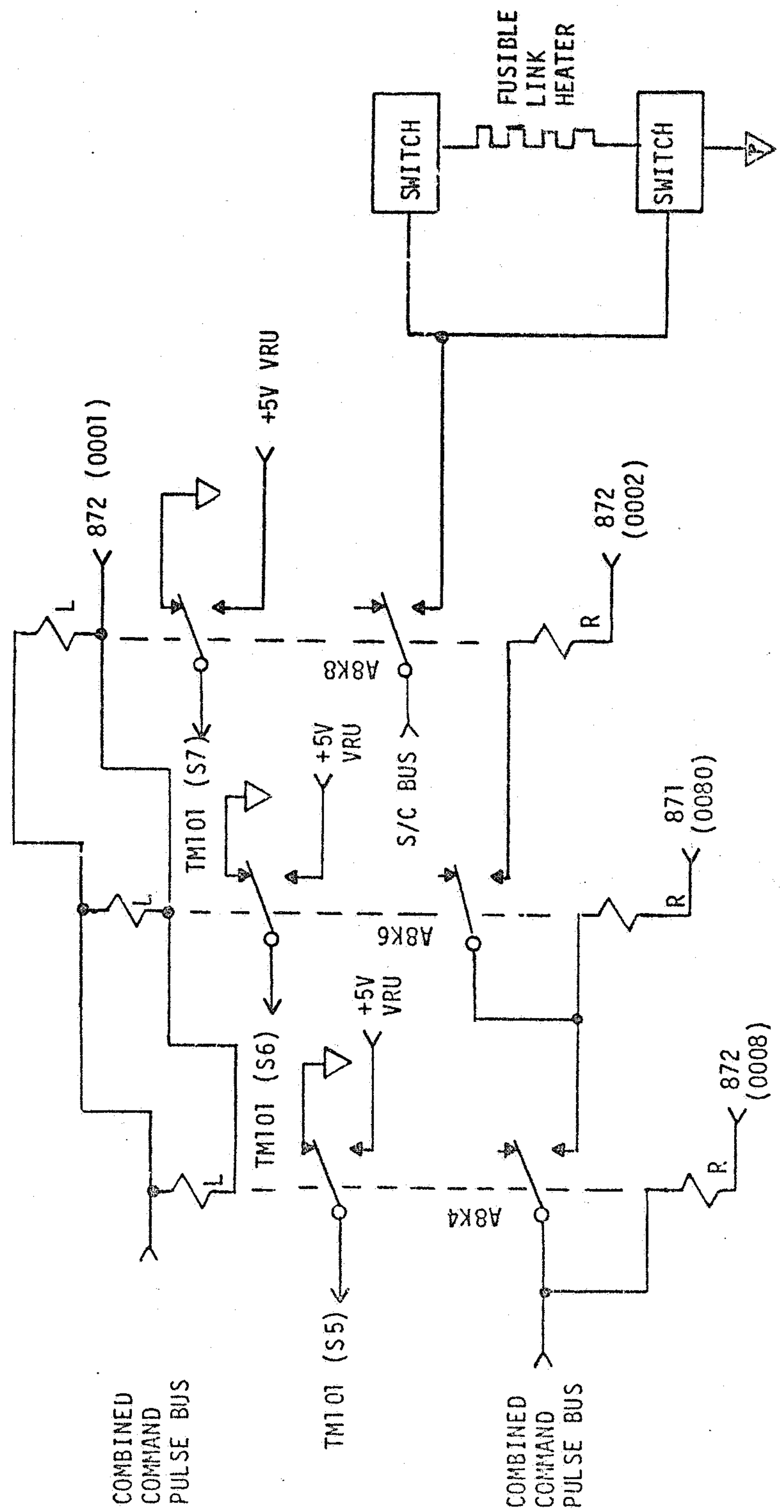


Figure 14.6-7. Shutter Fuse Links Control

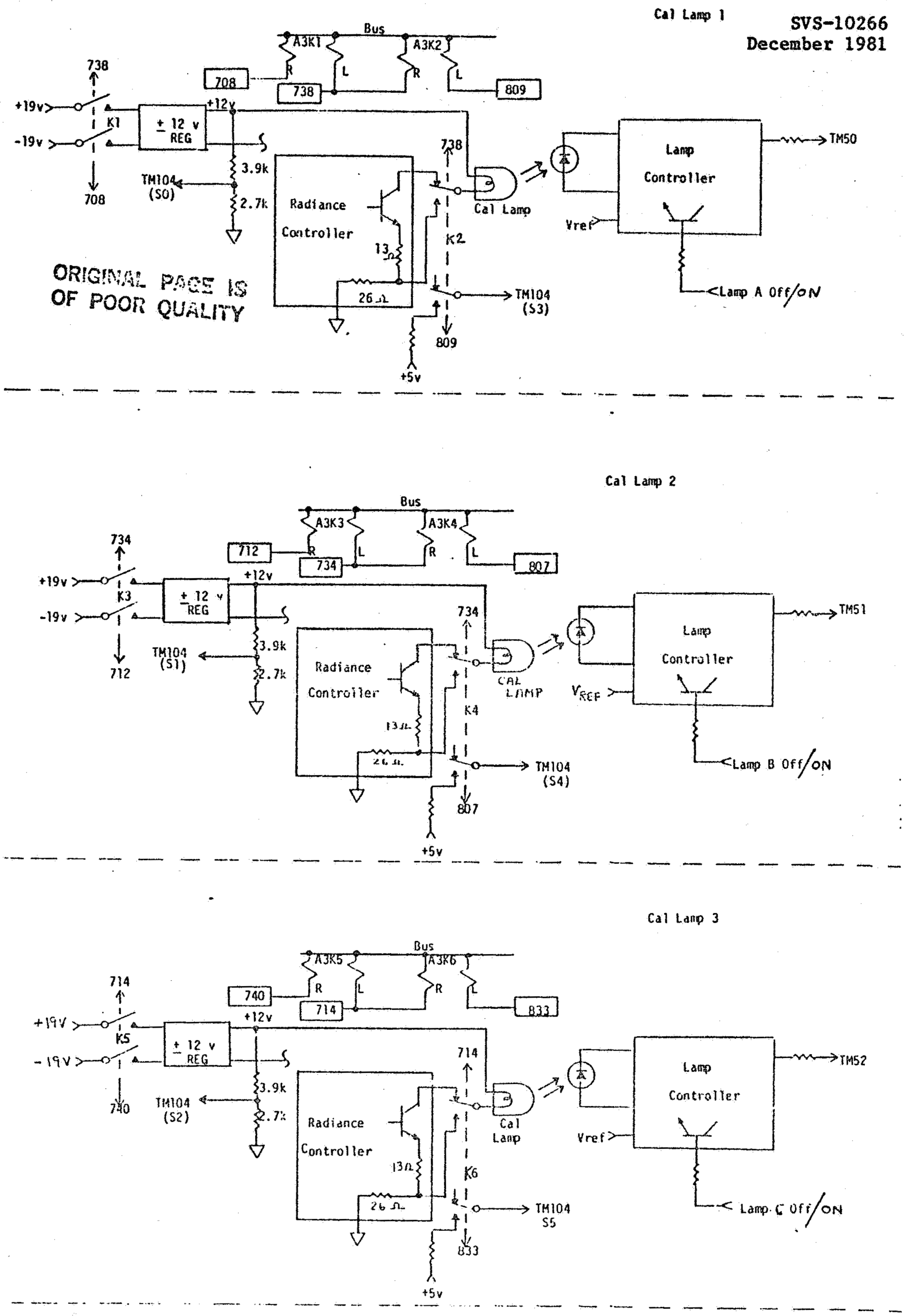


Figure 14.6-8. Cal Lamp Control

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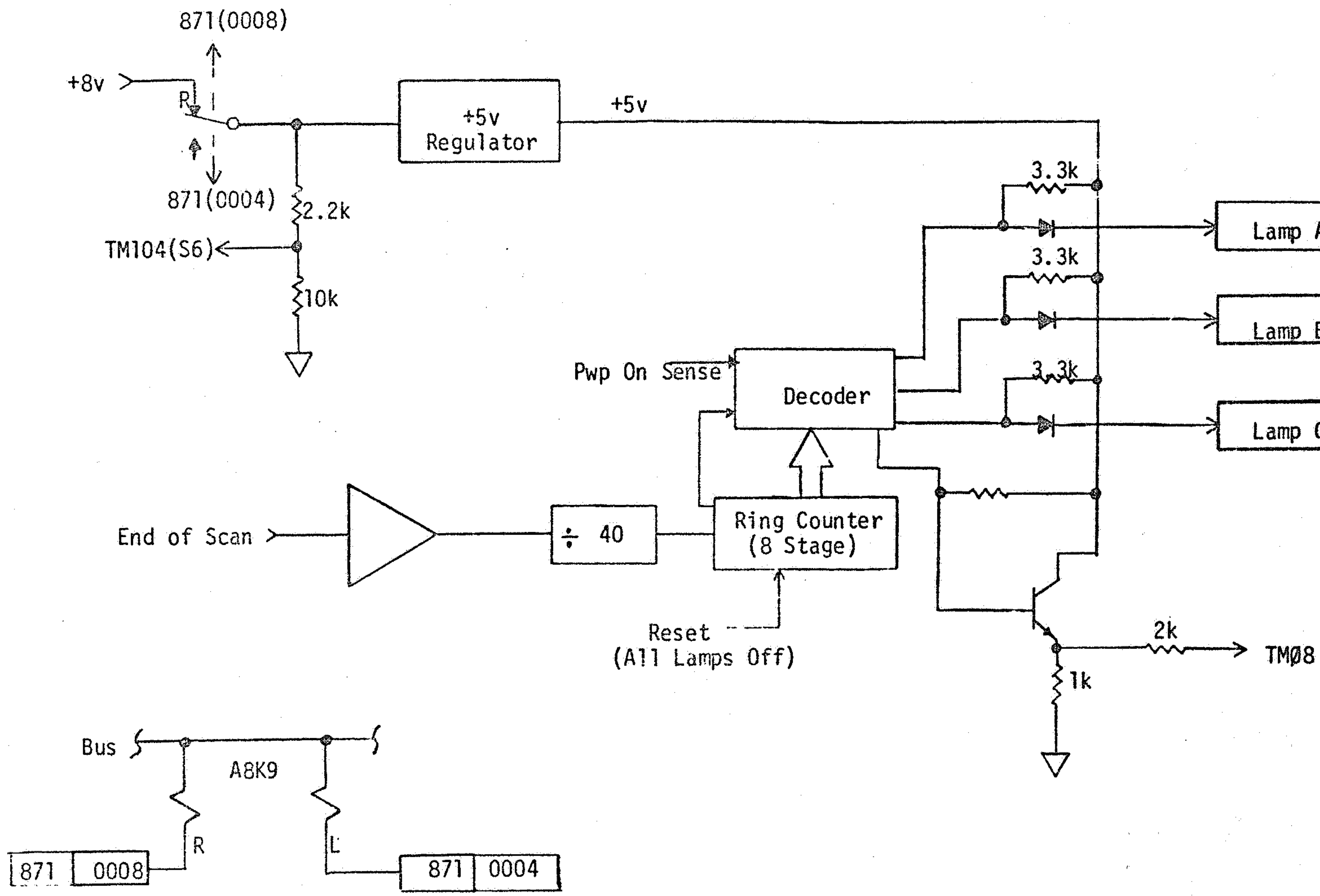

Figure 14.6-9. Calibration Sequence Control

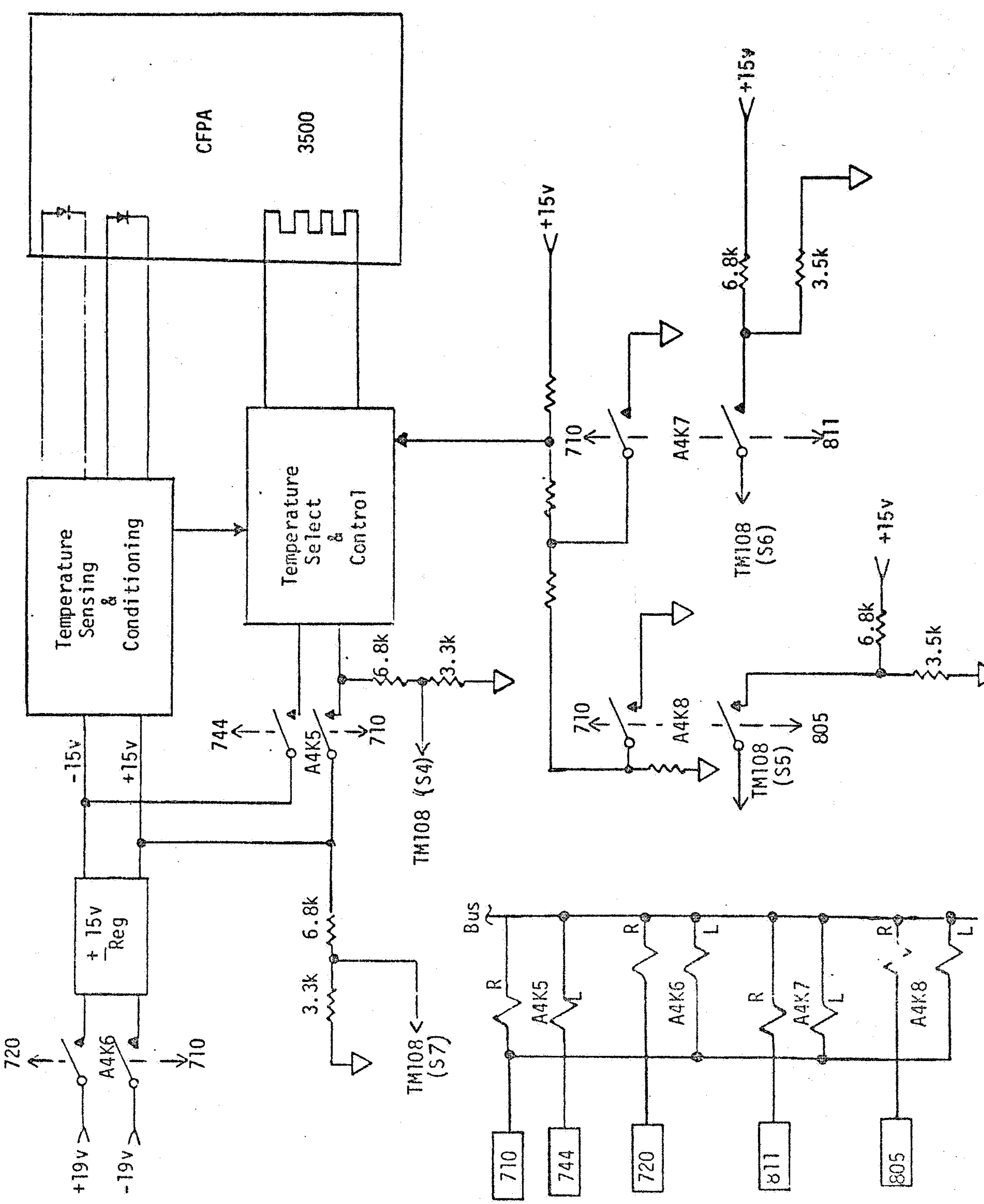

Figure 14.7-10. CFPA Temperature Control

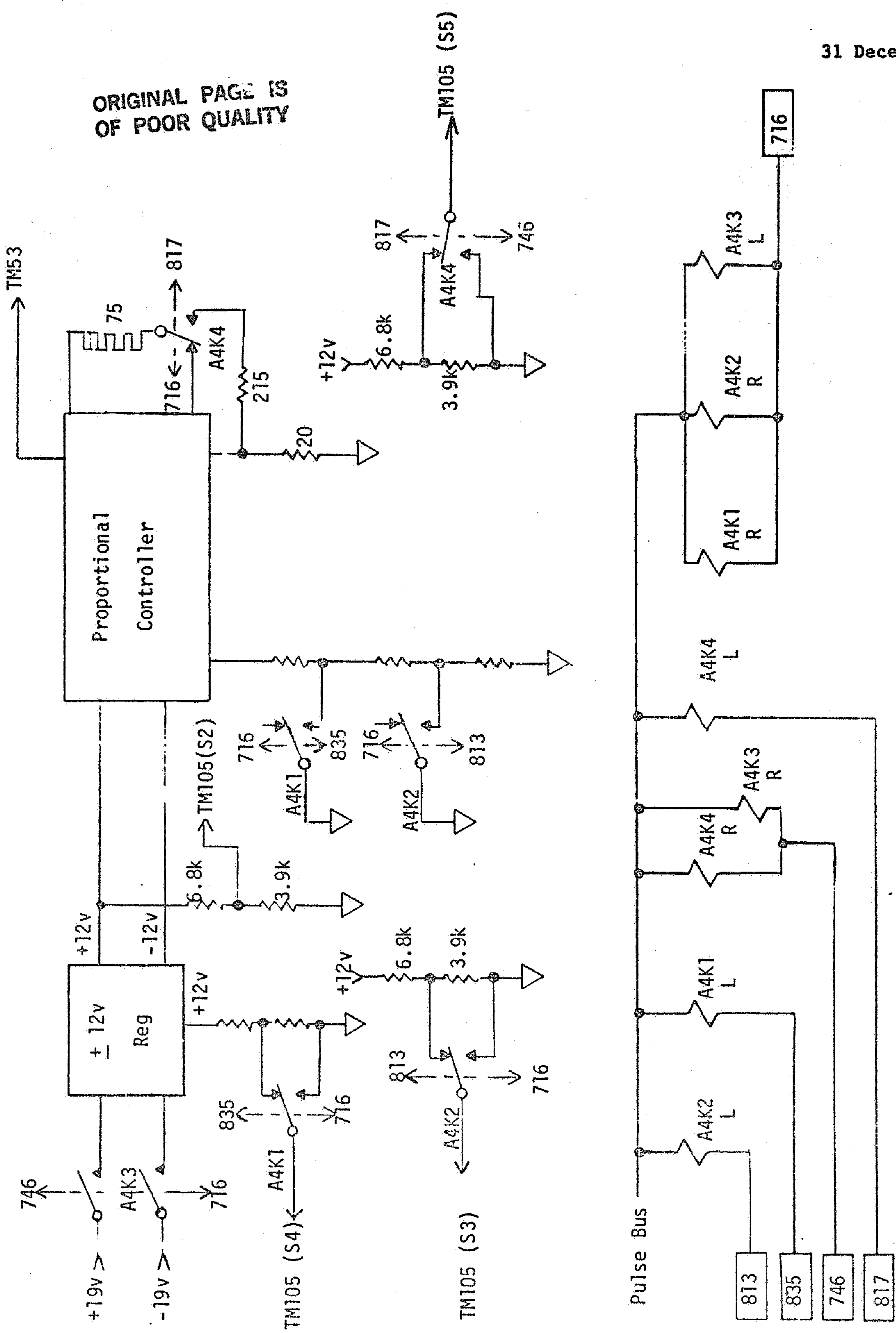

Figure 14.6-11. Blackbody Temperature Control

BAND	1	2	3	4	5	6	7
ON	718	754	728	758	819	847	815
OFF	752	724	756	730	845	825	841

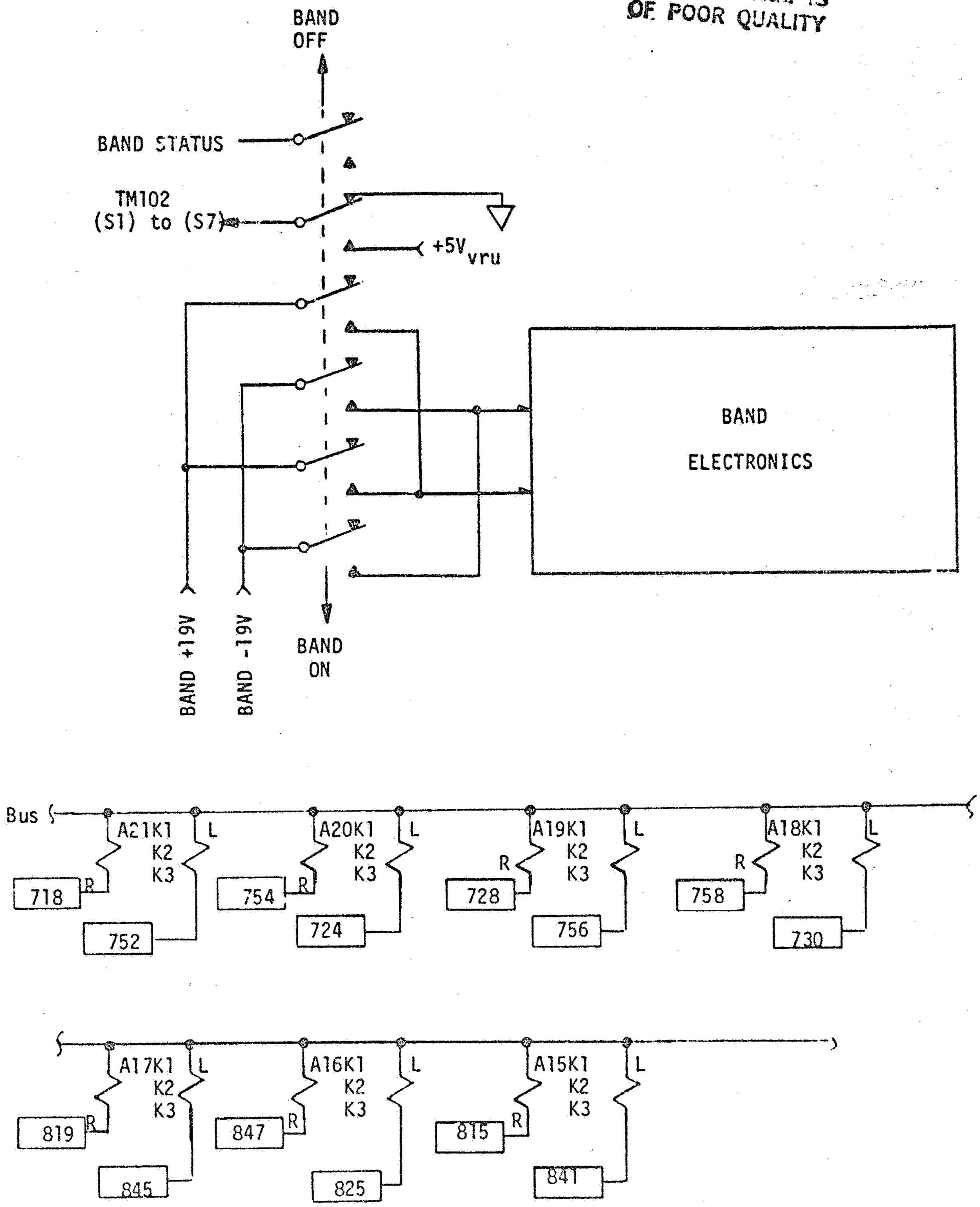

Figure 14.6-12. Band Control

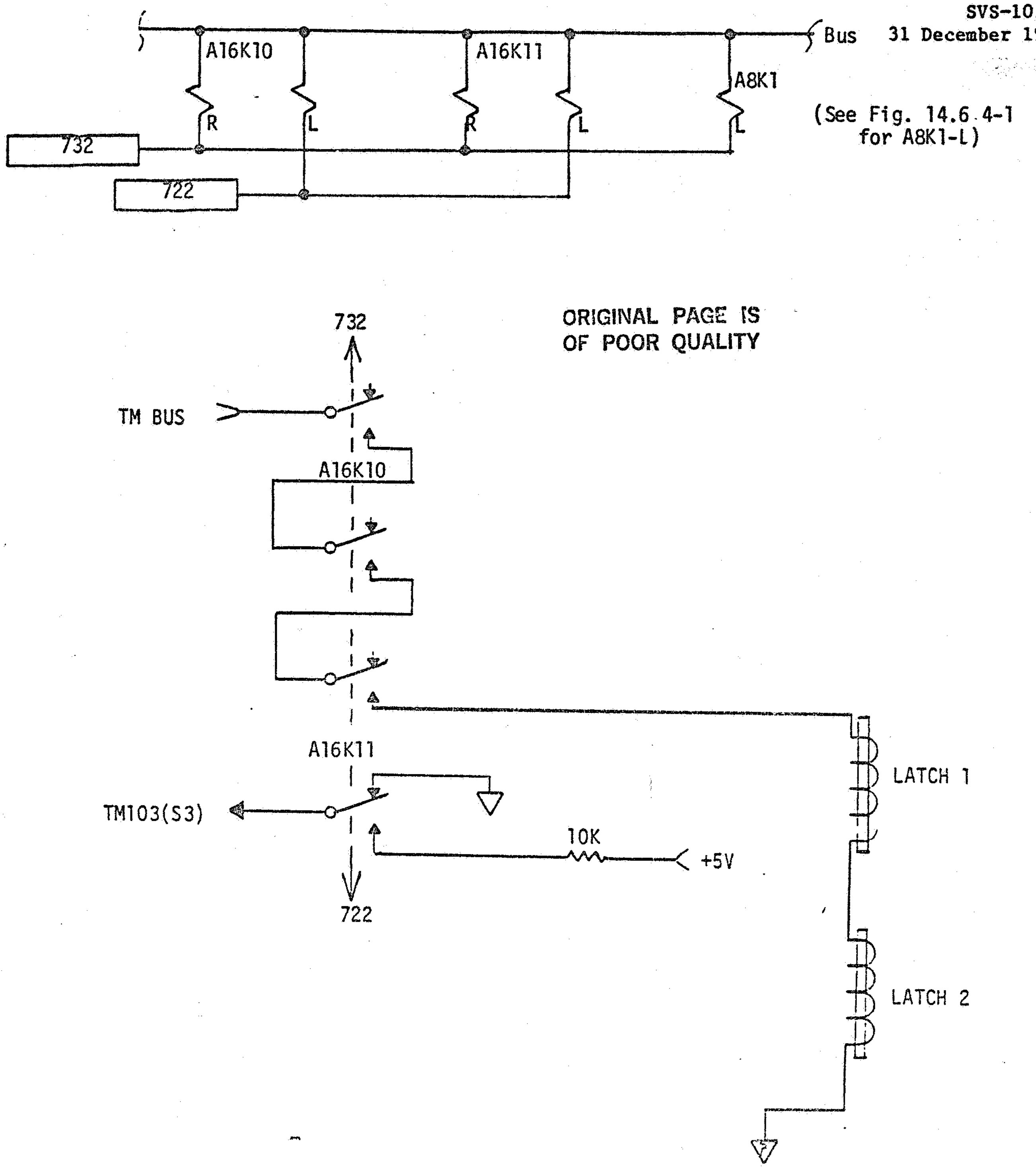

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Figure 14.6-13. Door Latch Control

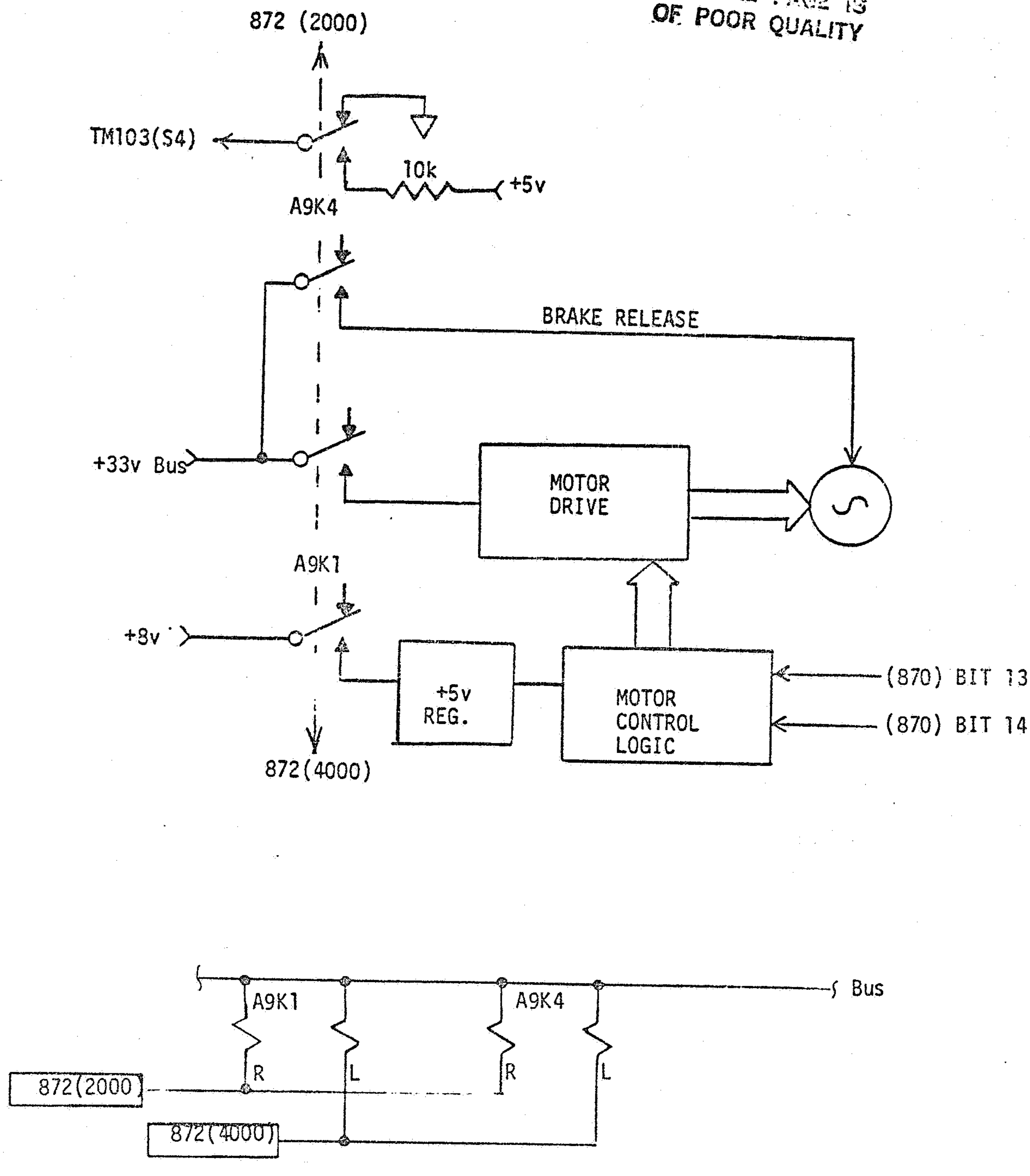

Figure 14.6-14. Door Operation

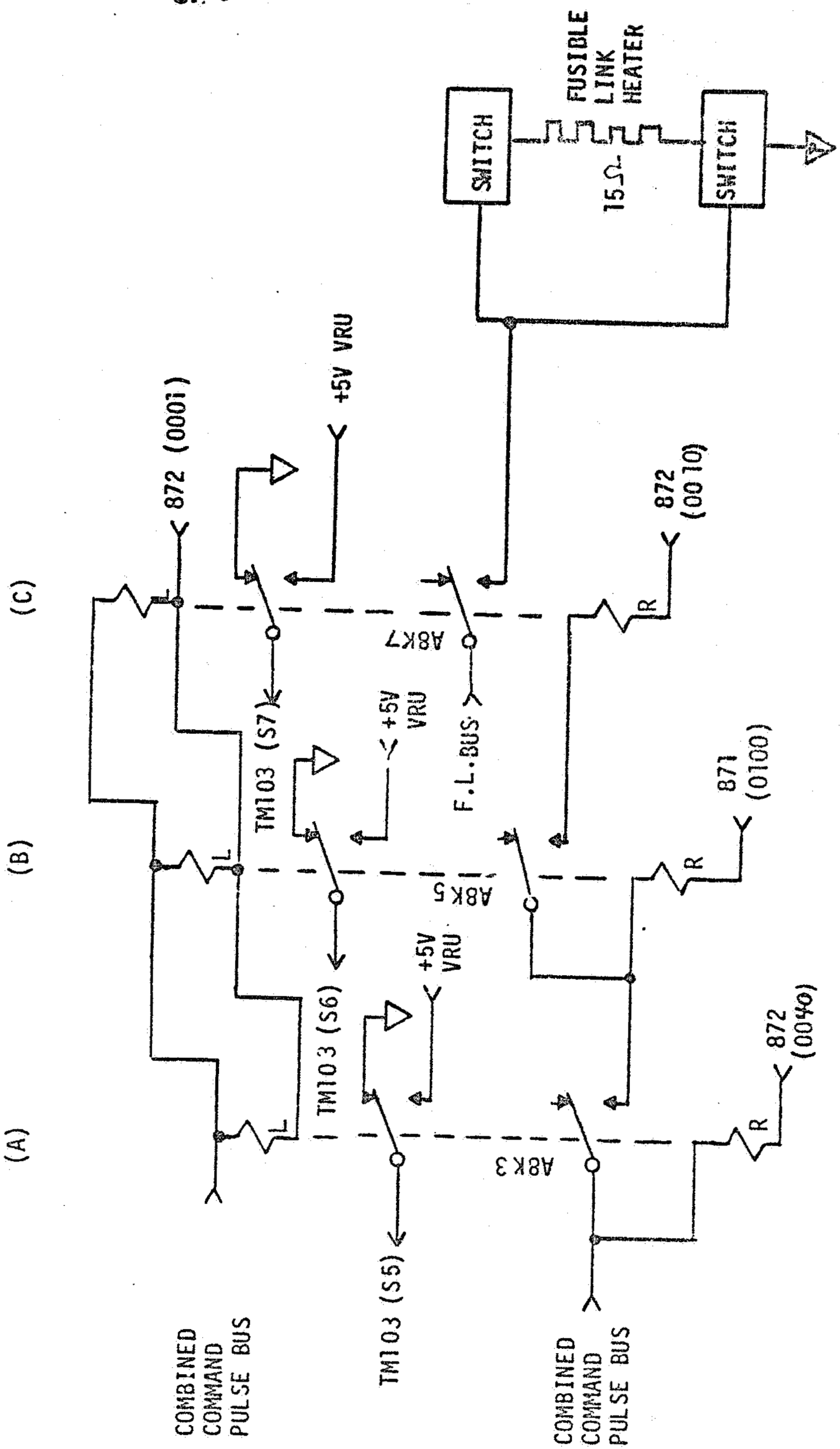

Figure 14.6-15. Door Fusible Link

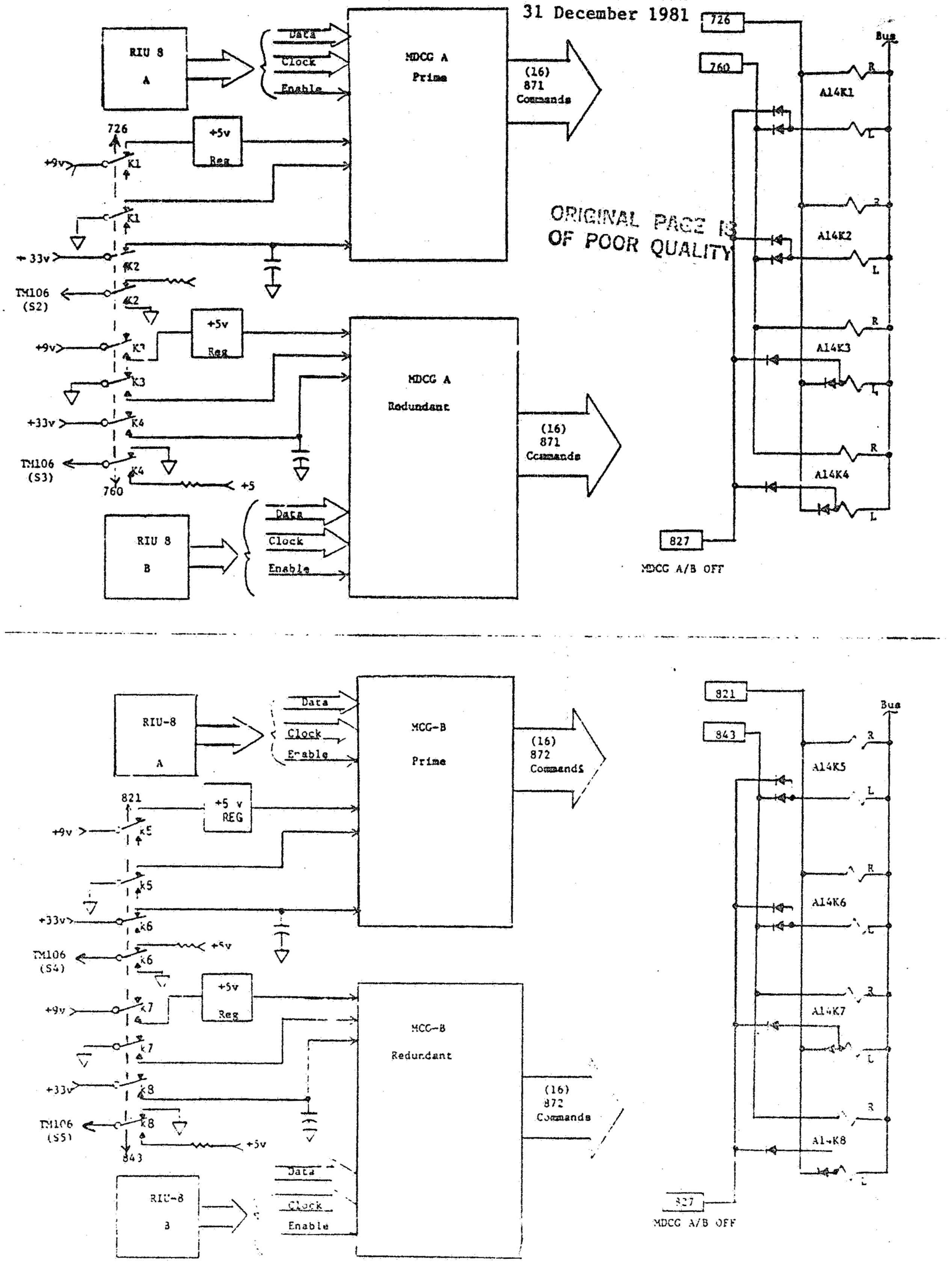

Figure 14.6-16. MCG Control

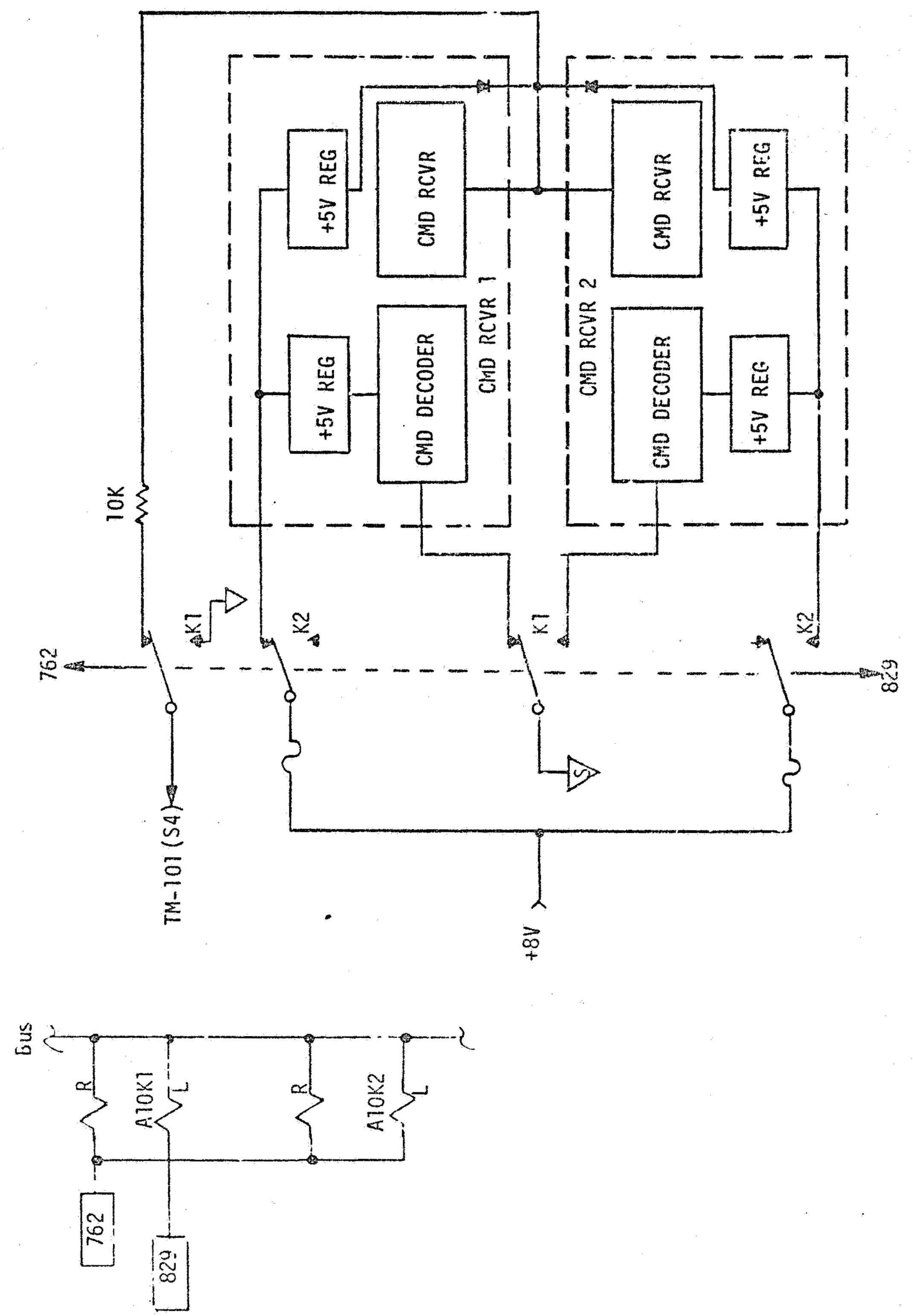

Figure 14.6-17. Serial Command Receivers Control

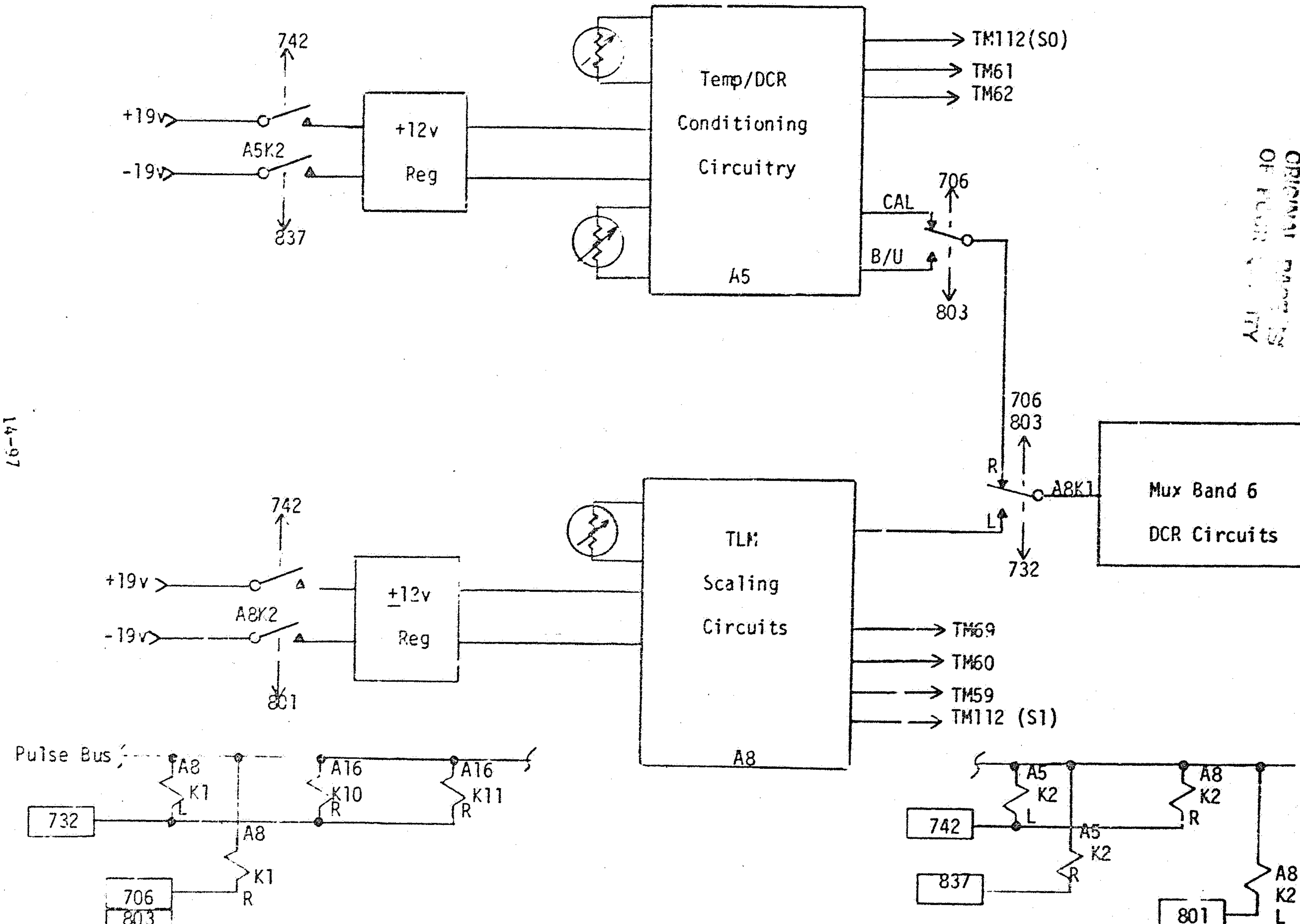

Figure 14.6-18. DC Restore Control and Telemetry Scaling Control

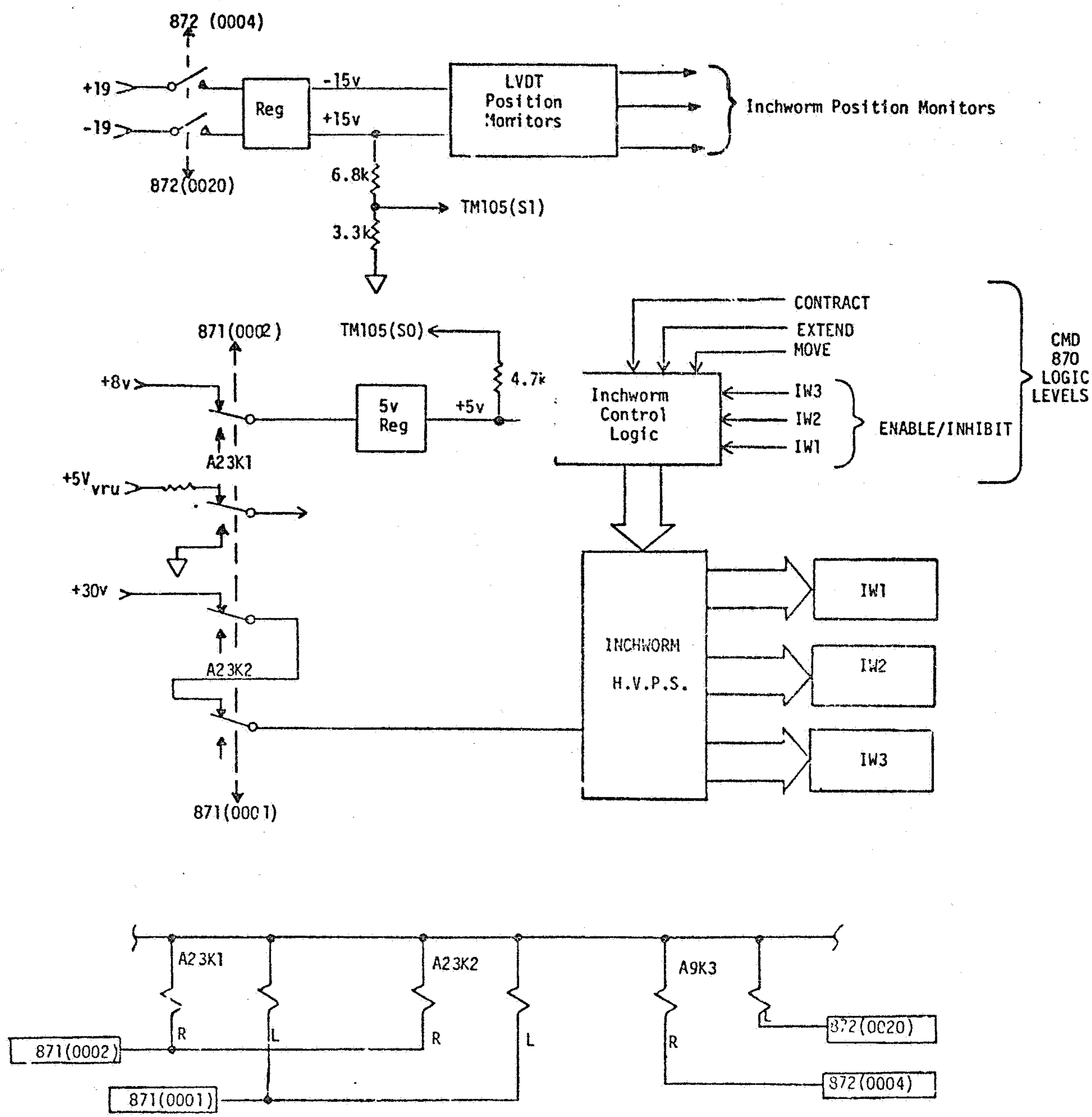

Figure 14.6-19. Inchworm Control

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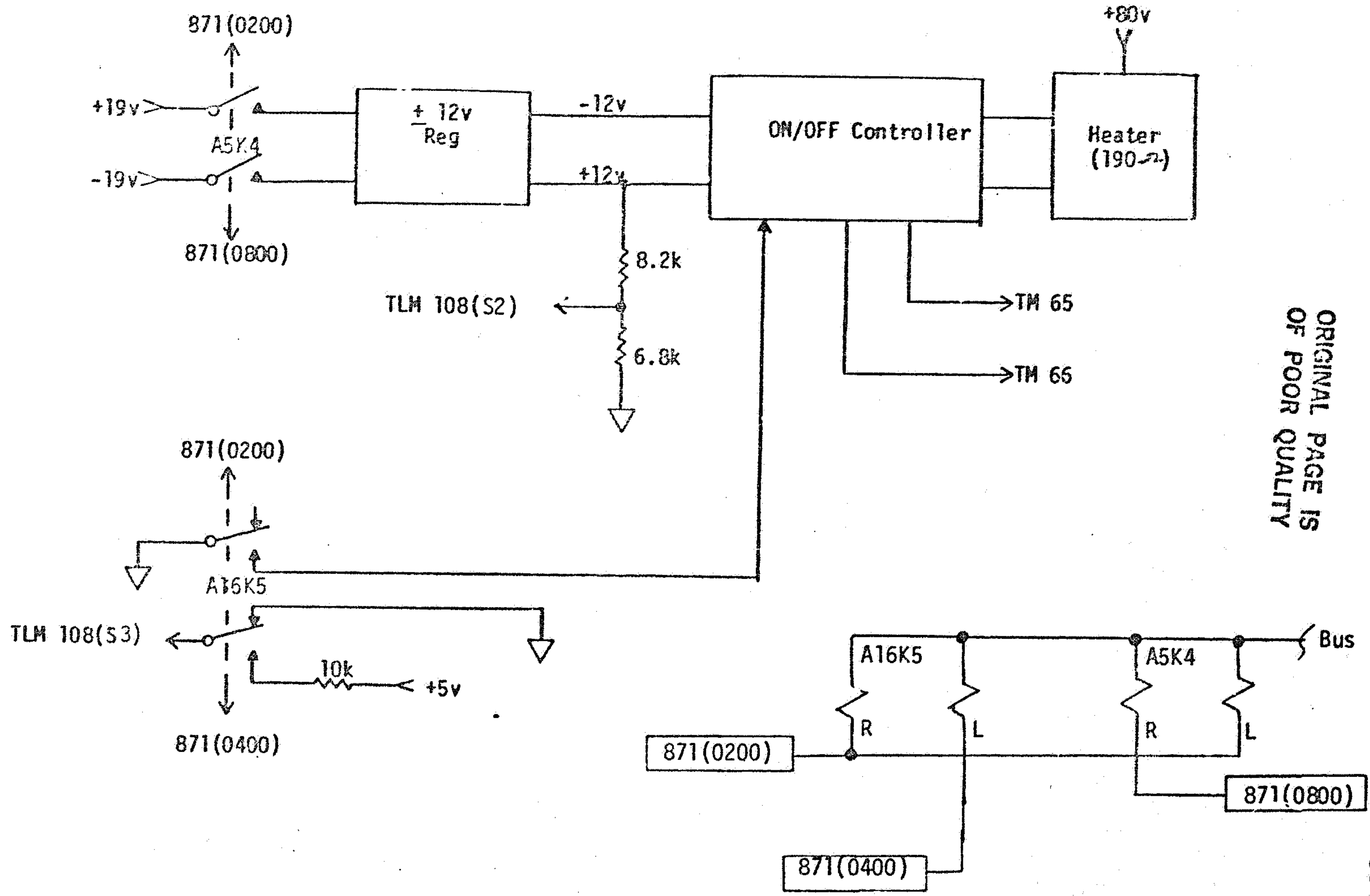

Figure 14.6-20. Intermediate Stage Temperature Control

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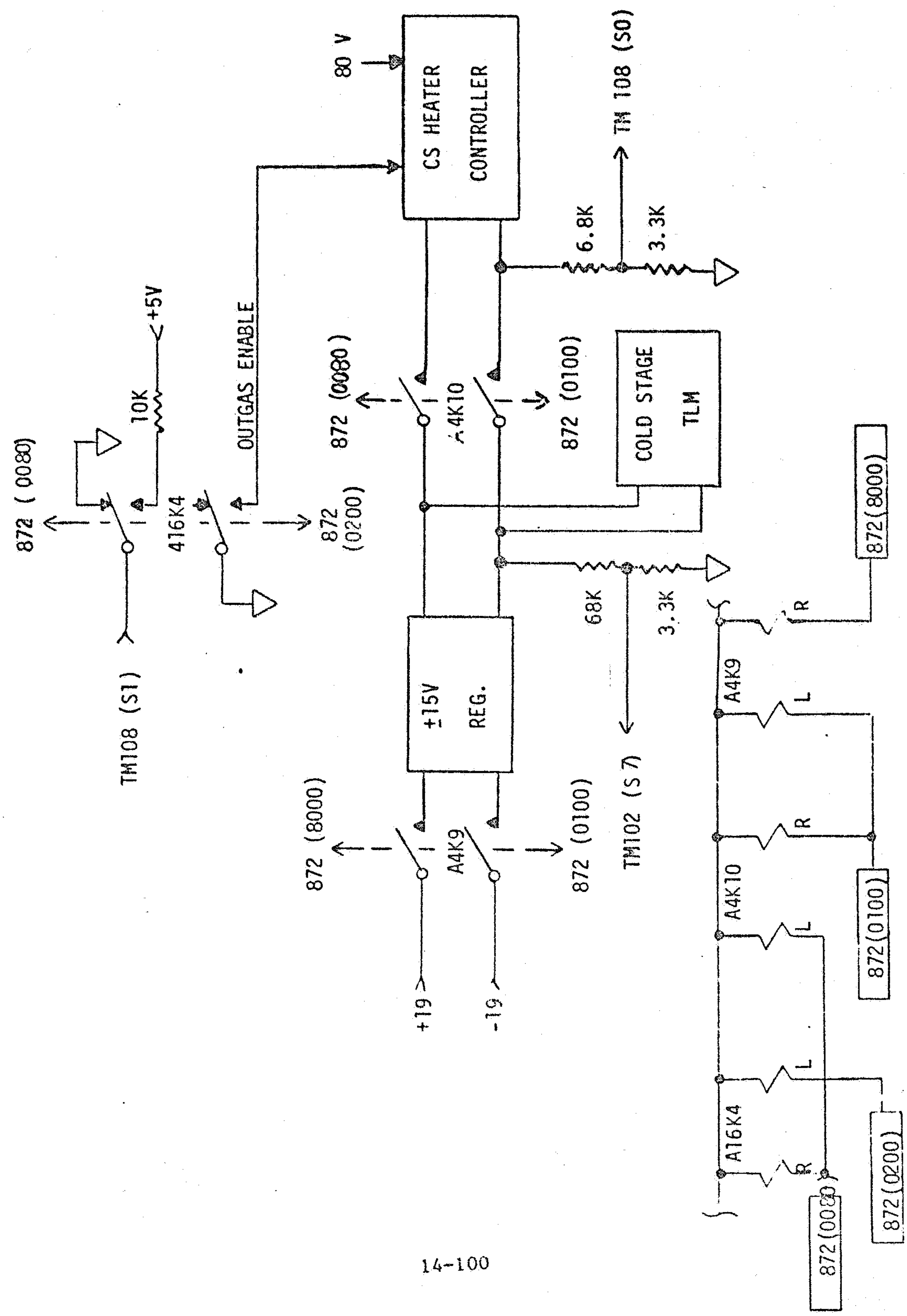

Figure. 14-6-21. Cold Stage Temperature Control

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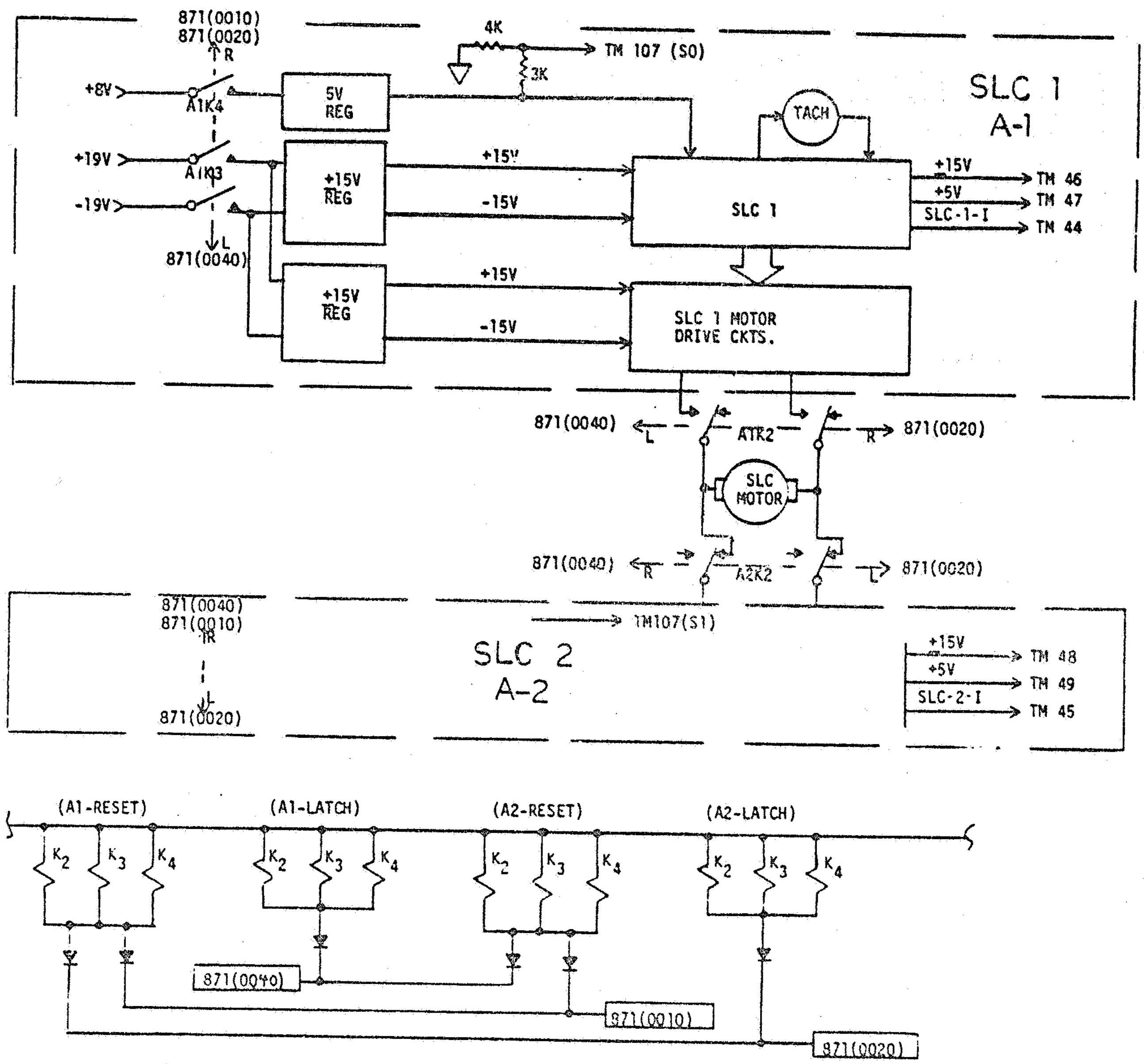

Figure 14.6-22. SLC Control

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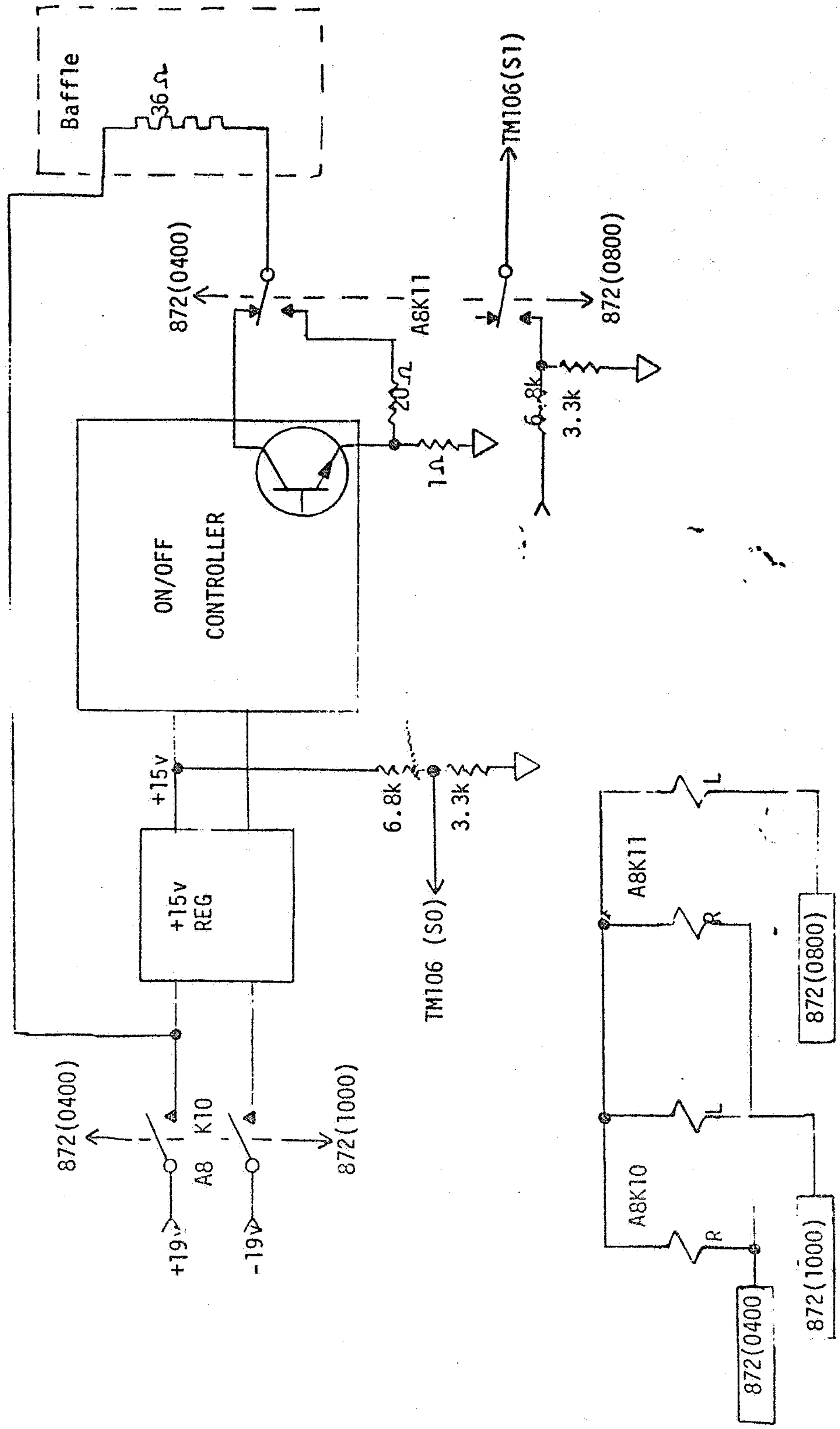

Figure 14.6-23. Baffle Temperature Control

Table 14.6-1. TM Command List

Command Name	Acronym	Riu-Channel	Serial Bits	Complement	Reference Paragraph
Power Supply 2 ON	PS2ON	605	—	615	14.6.1.1
Power Supply 2 OFF	PS2OFF	615	—	605	14.6.1.1
PS 2 to MUX ON	MUX2ON	621	—	631	14.6.1.2
PS 2 to MUX OFF	MUX2OFF	631	—	621	14.6.1.2
Power Supply 1 ON	PS1ON	632	—	642	14.6.1.1
Power Supply 1 OFF	PS1OFF	642	—	632	14.6.1.1
PS 1 to MUX ON	MUX1ON	648	—	658	14.6.1.2
PS 1 to MUX OFF	MUX1OFF	658	—	648	14.6.1.2
Thermal Shutdown Disable	THSDNDIS	702	—	736	14.6.1.1
SME 2 ON/1 OFF	SME2SEL	704	—	748/823	14.6.1.3
Calibration Shutter ON	CSHTRON	706	—	803/839	14.6.1.4
Cal Lamp 1 ON	LP1ON	708	—	738	14.6.1.5
CFPA Heater Control ON/Select T1	CFPAONT1	710	—	—	14.6.1.6
Cal Lamp 2 ON	LP2ON	712	—	734	14.6.1.5
Cal Lamp 3 OFF	LP3OFF	714	—	740	14.6.1.5
BB Heater Controller ON Select T1	BBHTRENA	716	—	—	14.6.1.7
Band 1 ON	BD1ON	718	—	752	14.6.1.8
CFPA Telemetry OFF	CFPATMOF	720	—	710	14.6.1.6
Door Electro Magnet ON	DMAGON	722	—	732	14.6.1.9
Band 2 OFF	BD2OFF	724	—	754	14.6.1.8
MDC Generator A Select Prime	SELPACG	726	—	760 & 827	14.6.1.10
Band 3 ON	BD3ON	728	—	756	14.6.1.8
Band 4 OFF	BD4OFF	730	—	758	14.6.1.8
Door Electro-Magnet Off	DMAGOFF	732	—	722	14.6.1.9
					14.6.1.11
Cal Lamp 2 OFF	LP2OFF	734	—	712	14.6.1.5
Thermal Shutdown Enable	THSDNENA	736	—	702	14.6.1.1
Cal Lamp 1 OFF	LP1OFF	738	—	708	14.6.1.5
Cal Lamp 3 ON	LP3ON	740	—	714	14.6.1.5
DC Restore & Telemetry Scaling OFF	DCRTMOFF	742	—	801 & 837	14.6.1.11
					14.6.1.12
CFPA Heater Controller OFF	CFPAOFF	744	—	710	14.6.1.6
BB Heater Controller & Backup OFF	BBHTRDIS	746	—	817 & 716	14.6.1.7
SME 1 ON and SME 2 OFF	SME1SEL	748	—	704 & 823	14.6.1.3
SAM 1 to SME 1	SAM1SEL	750	—	831	14.6.1.3
Band 1 OFF	BD1OFF	752	—	718	14.6.1.8
Band 2 ON	BD2ON	754	—	724	14.6.1.8
Band 3 OFF	BD3OFF	756	—	728	14.6.1.8
Band 4 ON	BD4ON	758	—	730	14.6.1.8

Table 14.6-1. TM Command List

Command Name	Acronym	Riu-Channel	Serial Bits	Complement	Reference Paragraph
MDC Generator A Select Redundant	SELRACG	760	—	726 & 827	14.6.1.10
Select Serial Command Receiver 1	SCR1SEL	762	—	829	14.6.1.10
Telemetry Scaling ON	TLMSCLON	801	—	742	14.6.1.12
Backup Shutter ON	BUSHTRON	803	—	706 & 839	14.6.1.4
CFPA Select Set Point T2	CFPA2SEL	805	—	630	14.6.1.6
Cal Lamp 2 Override ON	LP2ORON	807	—	734	14.6.1.5
Cal Lamp 1 Override ON	LP1ORON	809	—	738	14.6.1.5
CFPA Select Set Point T3	CFPA3SEL	811	—	710	14.6.1.6
Blackbody Select Set Point T2	BBT2SEL	813	—	716	14.6.1.7
Band 7 ON	BD7ON	815	—	841	14.6.1.8
Blackbody Heater ON Backup	BBBKUPON	817	—	716	14.6.1.7
Band 5 ON	BD5ON	819	—	845	14.6.1.8
MDC Generator B Select Prime	SELPBCG	821	—	827 & 843	14.6.1.10
Scan Mirror Electronics OFF	SMEOFF	823	—	704 & 748	14.6.1.3
Band 6 OFF	BD6OFF	825	—	847	14.6.1.8
MDC Generators OFF	MCGOFF	827	—	726,760,821 & 843	14.6.1.10
Serial Command Receiver 2 ON/OFF	SCR2SEL	829	—	762	14.6.1.10
SAM 2 to SME 2 & BPR to SAM 1	SAM2SEL	831	—	750	14.6.1.3
Cal Lamp 3 Override ON	LP3ORON	833	—	714	14.6.1.5
Select Blackbody Set Point T3	BBT3SEL	835	—	716	14.6.1.7
DC Restore ON	DCRON	837	—	742	14.6.1.11
Shutters OFF	SHTROFF	839	—	706 & 803	14.6.1.4
Band 7 OFF	BD7OFF	841	—	815	14.6.1.8
MDC Generator B Select Redundant	SELRBCG	843	—	827 & 821	14.6.1.10
Band 5 OFF	BD5OFF	845	—	819	14.6.1.8
Band 6 ON	BD6ON	847	—	825	14.6.1.8
Reset 870 Message	RST870	870	[0000]	—	14.6.1.13
Midscan Marker ON	MIDSCN	870	[0003]	—	14.6.1.2
Move Door Open Direction	DOROPN	870	[0008]	—	14.6.1.9
Move Door Close Direction	DORCLS	870	[000C]	—	1.6.1.9
Cycle Inchworm Logic	IWCYCL	870	[0200]	—	14.6.1.13
Inchworm 1 Extend	IW1EXT	870	[0310]	—	14.6.1.13
Inchworm 2 Extend	IW2EXT	870	[0320]	—	14.6.1.13
Inchworm 3 Extend	IW3EXT	870	[0340]	—	14.6.1.13
Inchworm 1 Contract	IW1CNT	870	[0290]	—	14.6.1.13
Inchworm 2 Contract	IW2CNT	870	[02A0]	—	14.6.1.13
Inchworm 3 Contract	IW3CNT	870	[02C0]	—	14.6.1.13
SMA +Z Heater Enable	PSMAENA	871	8000	871(4000)	14.6.1.3

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Table 14.6-1. TM Command List

Command Name	Acronym	Riu-Channel	Serial Bits	Complement	Reference Paragraph
SMA +Z Heater Controller OFF	PSMADIS	871	4000	871(8000)	14.6.1.3
SMA -Z Heater Enable	NSMAENA	871	2000	871(1000)	14.6.1.3
SMA -Z Heater Controller OFF	NSMADIS	871	1000	871(2000)	14.6.1.3
Intermediate Stage Outgas Enable	ISOUTENA	871	0800	871(0200)	14.6.1.14
Intermediate Stage Controller ON	ENAISTC	871	0400	871(0200)	14.6.1.14
				871[0800]	
Intermediate Stage Controller OFF	DISISTC	871	0200	871[0400]	14.6.1.14
Cooler Door Fusible Link Arm	DFLARM	871	0100	872(0001)	14.6.1.9
Shutter Fusible Link Arm	SFLARM	871	0080	872(0001)	14.6.1.4
Select SLC 1	SLC1SEL	871	0040	871[0010]	14.6.1.15
Select SLC 2	SLC2SEL	871	0020	871[0010]	14.6.1.15
SLC OFF	SLCOFF	871	0010	871[0020] [0040]	14.6.1.15
Lamp Sequencer ON	SEQON	871	0008	871[0004]	14.6.1.5
Lamp Sequencer OFF	SEQOFF	871	0004	871(0008)	14.6.1.5
Inchworm ON	IWON	871	0002	871(0001)	14.6.1.13
Inchworm OFF	IWOFF	871	0001	871(0002)	14.6.1.13
Cold Stage Telemetry OFF	CSTLMOFF	872	8000	—	14.6.1.14
Cooler Door Motor ON	DMTRON	872	4000	872(2000)	14.6.1.9
Cooler Door Motor OFF	DMTROFF	872	2000	872(4000)	14.6.1.9
Baffle Heater Controller ON	BFHTRENA	872	1000	872(0400)	14.6.1.16
Baffle Heater Backup ON	BFHTRBU	872	0800	872(0400)	14.6.1.16
				872[0800]	
Baffle Heater OFF	BFHTRDIS	872	0400	872[0800]	14.6.1.16
Cold Stage Outgas Heater Enable	CSOUTENA	872	0200	872(0080)	14.6.1.14
Cold Stage Heater Controller ON	ENACSHTR	872	0100	872(0080)	14.6.1.14
Cold Stage Heater OFF	DISCSHTR	872	0080	—	14.6.1.14
Cooler Door Fusible Line Enable	DFLENA	872	0040	872(0001)	14.6.1.9
LVDT ON	LVDTON	872	0020	872(0004)	14.6.1.13
Cooler Door Fusible Link Fire	DFLFIRE	872	0010	872(0001)	14.6.1.9
Shutter Fusible Link Enable	SFLENA	872	0008	872(0001)	14.6.1.4
LVDT OFF	LVDTOFF	872	0004	872(0020)	14.6.1.13
Shutter Fusible Link Fire	SFLFIRE	872	0002	872(0001)	14.6.1.4
Fuselink Safe	FLSAFE	872	0001	—	14.6.1.4

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Table 14.6-2. PDU (TM) Commands

Command Name	Acronym	Riu-Channel	Serial Bits	Complement	Reference Paragraph
TM +/-19V Power Supply ON	TM19ON	616	—	645	
TM +/-19V Power Supply OFF	TM19OFF	645	—	616	
TM Power A Enable	ENATMA	634	—	662/655	
TM Power B Enable	ENATMB	607	—	662/655	
TM Power Disable	DISTM	662	—	634/607	
TM SMA Heater Enable	ENSMAHTR	601	—	636	
TM SMA Heater Disable	DSSMAHTR	636	—	601	
TM Ext Stby Heater Enable	EXSBYHTR	610	—	639	
TM Ext Stby Heater Disable	DXSBYHTR	639	—	610	
TM Fusible Links Power Enable	ENFSLINK	609	—	638	
TM Fusible Links Power Disable	DSFSLINK	638	—	609	
Payloads OFF	PLOFF	655	—	—	
TM +/-19V Select Power Supply A	TM19 A	617	—	646	
TM +/-19V Select Power Supply B	TM19 B	646	—	617	

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Table 14.6-3. SC & CU (TM) Commands

Command Name	Acronym	Riu-Channel	Serial Bits	Complement	Reference Paragraph
TM Safehold Heater 1 Enable	TMHAEN	470	1476	[24B6]	
TM Safehold Heater 1 Disable	TMHADI	470	24B6	[1476]	
TM Safehold Heater 2 Enable	TMHBEN	470	3436	[3436]	
TM Safehold Heater 2 Disable	TMHBDI	470	44D6	[4406]	
TM Safehold Heater Thermostat Bypass	TMTHBY	470	5456	[6496]	
TM Safehold Heater Thermostat Enable	TMTHEN	470	6496	[5456]	

14.7 TM TELEMETRY

Operation of the Thematic Mapper is monitored by 70 conditioned analog telemetry channels, 30 passive analog telemetry channels and 12 serial digital telemetry channels. The telemetry monitors are listed in Table 14.7-1. Telemetry limits appear in Table 14.7-2. Telemetry derivation circuits appear in paragraph 14.7.3.

14.7.1 TM ANALOG TELEMETRY MONITORS

The Thematic Mapper utilizes 100 analog telemetry channels (70 conditioned and 30 passive). The telemetry monitors are listed by user identification number in Table 14.7-1, and operating limits appear in Table 14.7-2. Information regarding calibration curve coefficients for the telemetry response functions can be found in Appendix A.14.

The following paragraphs describe the telemetry monitors.

14.7.1.1 Power Supply #1 Input Current (TM-01)

This telemetry function monitors the input current to Thematic Mapper power supply number 1. The input current is monitored by sensing the voltage drop across a resistor in the input power return line. The telemetry derivation circuit appears in Figure 14.7-1.

Table 14.7-1. TM Telemetry List

USER ID		ACRONYM	SIG TYPE	MATRIX LOC MISSION	MATRIX LOC ENGR	RIU # - CH	REFERENCE PARAGRAPH
TM-01	Power Supply #1 Input Current	TMPS1I	A	99(18) 99(50) 99(82) 99(114)		06-64	4.7.1.1
TM-02	Power Supply #2 Input Current	TMPS2I	A	99(19) 99(51) 99(83) 99(115)		06-65	14.7.1.2
TM-03	+19V High Current Supply Monitor	TM19VP	A	32(15)	32(15)	06-66	14.7.1.3
TM-04	-19V High Current Supply Monitor	TM19VN	A	32(16)	32(16)	06-67	14.7.1.4
TM-05	+8V Supply Monitor	TM8V	A	99(20) 99(52) 99(84) 99(116)	99(20) 99(52) 99(84) 99(116)	06-68	14.7.1.5
TM-06	+80V Heater Supply Voltage	TM80V	A	32(19)	32(19)	06-71	14.7.1.6
TM-07	+33V Shutter Drive Voltage	TM33V	A	32(18)	32(18)	06-70	14.7.1.7
TM-08	All Cal Lamps On	TMLMPS	A	32(17)	32(17)	06-102	14.7.1.8
TM-09	Band 1 +19V Supply Voltage	TM119VP	A	32(32)	32(32)	07-120	14.7.1.9
TM-10	Band 1 -19V Supply Voltage	TM119VN	A	32(33)	32(33)	07-121	14.7.1.10
TM-11	Band 2 +19V Supply Voltage	TM219VP	A	32(34)	32(34)	07-122	14.7.1.11

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Table 14.7-1. TM Telemetry List

USER ID		ACRONYM	SIG TYPE	MATRIX LOC MISSION	MATRIX LOC ENGR	RIU # - CH	REFERENCE PARAGRAPH
TM-12	Band 2 -19V Supply Voltage	TM219VN	A	32(35)	32(35)	07-123	14.7.1.12
TM-13	Band 3 +19V Supply Voltage	TM319VP	A	32(36)	32(36)	07-124	14.7.1.13
TM-14	Band 3 -19V Supply Voltage	TM319VN	A	32(37)	32(37)	07-125	14.7.1.14
TM-15	Band 4 +19V Supply Voltage	TM419VP	A	32(38)	32(38)	07-126	14.7.1.15
TM-16	Band 4 -19V Supply Voltage	TM419VN	A	32(39)	32(39)	07-127	14.7.1.16
TM-17	Band 5/7 +19V Supply Voltage	TM519VP	A	32(40)	32(40)	07-104	14.7.1.17
TM-18	Band 5/7 -19V Supply Voltage	TM519VN	A	32(41)	32(41)	07-105	14.7.1.18
TM-19	Band 6 +19V Supply Voltage	TM619VP	A	32(42)	32(42)	07-106	14.7.1.19
TM-20	Band 6 -19V Supply Voltage	TM619VN	A	32(43)	32(43)	07-107	14.7.1.20
TM-21	Isolated +19V Supply Voltage	TMI19VP	A	32(44)	32(44)	07-108	14.7.1.21
TM-22	Isolated -19V Supply Voltage	TMI19VN	A	32(45)	32(45)	07-109	14.7.1.22
TM-23	CDVU +9V Supply Voltage	TMVU9V	A	99(21) 99(53) 99(85) 99(117)	99(21) 99(53) 99(85) 99(117)	07-110	14.7.1.23
TM-24	Power Supply 1 +6.8V SMA Supply Voltage	TM17V	A	32(55)	32(55)	06-104	14.7.1.24
TM-25	Power Supply 1 +27V SMA Supply Voltage	TM127VP	A	32(56)	32(56)	06-105	14.7.1.25

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Table 14.7-1. IM Telemetry List

USER ID		ACRONYM	SIG TYPE	MATRIX LOC MISSION	MATRIX LOC ENGR	RIU Ø - CH	REFERENCE PARAGRAPH
IM-26	Power Supply 1 -27V SMA Supply Voltage	IM127VN	A	32(57)	32(57)	06-106	14.7.1.26
IM-27	Power Supply 2 +6.8V SMA Supply Voltage	IM27V	A	32(58)	32(58)	06-107	14.7.1.27
IM-28	Power Supply 2 +27V SMA Supply Voltage	IM27VP	A	32(59)	32(59)	06-108	14.7.1.28
IM-29	Power Supply 2 -27V SMA Supply Voltage	IM227VN	A	32(60	32(60)	06-109	14.7.1.29
IM-30	+30V Multiplexer Supply Voltage	IMUX30V	A	32(48)	32(48)	06-110	14.7.1.30
IM-31	Multiplexer Input Current	IMUXI	A	32(46)	32(46)	06-126	14.7.1.31
IM-32	Multiplexer Average Bit Density	TBITDEN	A	32(47)	32(47)	06-120	14.7.1.32
IM-33	Multiplexer +5V Supply Voltage	IMUX5VP	A	32(49)	32(49)	06-121	14.7.1.33
IM-34	Multiplexer +18V Supply Voltage	IMUX18V	A	32(51)	32(51)	06-122	14.7.1.34
IM-35	Multiplexer -3V Supply Voltage	IMUX3VN	A	32(52)	32(52)	06-123	14.7.1.35
IM-36	Multiplexer -5V Supply Voltage	IMUX5VN	A	32(53)	32(53)	06-124	14.7.1.36
IM-37	Multiplexer -13V Supply Voltage	IMUX13VN	A	32(54)	32(54)	06-125	14.7.1.37
IM-38	Band 1 A/D Reference Voltage	IM1ADVR	A	32(61)	32(61)	06-112	14.7.1.38
IM-39	Band 2 A/D Reference Voltage	IM2ADVR	A	32(62)	32(62)	06-113	14.7.1.39
IM-40	Band 3 A/D Reference Voltage	IM3ADVR	A	32(65)	32(6[illegible])	06-114	14.7.1.40
IM-41	Band 4 A/D Reference Voltage	IM4ADVR	A	22(66)	32(64)	06-115	14.7.1.41

Table 14.7-1. TM Telemetry List

USER ID		ACRONYM	SIG TYPE	MATRIX LOC MISSION	MATRIX LOC ENGR	RIU # - CH	REFERENCE PARAGRAPH
TM-42	Band 5 A/D Reference Voltage	TM5ADVR	A	32(68)	32(68)	06-116	14.7.1.42
TM-43	Band 7 A/D Reference Voltage	TM7ADVR	A	32(70)	32(70)	06-117	14.7.1.43
TM-44	SCL 1 Drive Current	TMSLC1I	A	32(08)	32(08)	07-112	14.7.1.44
TM-45	SLC 2 Drive Current	TMSLC2I	A	32(09)	32(09)	07-113	14.7.1.45
TM-46	SLC 1 ± 15V Supply Voltages	TSL115V	A	32(10)	32(10)	07-114	14.7.1.46
TM-47	SLC 1 +5V Supply Voltage	TSL15VP	A	32(13)	32(13)	07-115	14.7.1.47
TM-48	SLC 2 ± 15V Supply Voltages	TSL215V	A	32(11)	32(11)	07-116	14.7.1.48
TM-49	SLC 2 +5V Supply Voltage	TSL25VP	A	32(14)	32(14)	07-117	14.7.1.49
TM-50	Cal Lamp 1 Current	TMLMP1I	A	32(12) 44	32(12)	08-12	14.7.1.50
TM-51	Cal Lamp 2 Current	TMLMP2I	A	32(31) 45	32(31)	08-13	14.7.1.51
TM-52	Cal Lamp 3 Current	TMLMP3I	A	32(50) 46	32(50)	08-14	14.7.1.52
TM-53	Blackbody Heater Current	TBBHTRI	A	32(69)	32(69)	07-118	14.7.1.53
TM-54	Baffle Heater Current	TBFHTRI	A	32(117)	32(117)	07-111	14.7.1.54
TM-55	Cold Stage Heater Current	TCSHTRI	A	32(107)	32(107)	08-15	14.7.1.55

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Table 14.7-1. TM Telemetry List

USER ID		ACRONYM	SIG TYPE	MATRIX LOC MISSION	MATRIX LOC ENGR	RIU # - CH	REFERENCE PARAGRAPH
TM-56	Inchworm 1 Position	TIW1POS	A	32(71)	32(71)	07-119	14.7.1.56
TM-57	Inchworm 2 Position	TIW2POS	A	32(72)	32(72)	07-86	14.7.1.57
TM-58	Inchworm 3 Position	TIW3POS	A	32(73)	32(73)	07-87	14.7.1.58
TM-59	Blackbody Temperature	TBBT	A	32(74) 47	32(74)	06-72	14.7.1.59
TM-60	Silicon Focal Plane Temperature	TSIFPT	A	32(75) 48	32(75)	06-73	14.7.1.60
TM-61	Calibration Shutter Temperature	TCALST	A	32(78) 49	32(78)	06-74	14.7.1.61
TM-62	Back-Up Shutter Temperature	TBUST	A	32(80) 50	32(80)	06-75	14.7.1.62
TM-63	Cold Stage Temperature A (Cold)	TCSCT	A	32(81)	32(81)	06-79	14.7.1.63
TM-64	Cold Stage Temperature B (Hot)	TCSHT	A	32(82)	32(82)	06-96	14.7.1.64
TM-65	Intermediate Stage Temperature A	TISCT	A	32(83)	32(83)	06-97	14.7.1.65
TM-66	Intermediate Stage Temperature B	TISHT	A	32(84)	32(84)	06-98	14.7.1.66
TM-67	Cold Focal Plane Assembly Control Temp.	TCFPACT	A	32(118)	32(118)	06-100	14.7.1.67
TM-68	Cold Focal Plane Assembly Heater Current	TCFPAHI	A	32(88)	32(88)	06-101	14.7.1.68
TM-69	Baffle Temperature	TBAFFT	A	32(87) 53	32(87)	06-76	14.7.1.69

Table 14.7-1. TM Telemetry List

USER ID		ACRONYM	SIG TYPE	MATRIX LOC MISSION	MATRIX LOC ENGR	RIU # - CH	REFERENCE PARAGRAPH
TM-70	Cold Focal Plane Array Monitor Temp.	TCFPAMT	A	32(89) 51	32(89)	06-99	14.7.1.70
TM-71	Ambient Odd Pre Amp Temperature	TAOPAT	P	32(90)	32(90)	07-80	14.7.1.71
TM-72	Cold Preamp Temperature	TCPAT	P	32(91)	32(91)	07-88	14.7.1.72
TM-73	Relay Optics Temperature	TROT	P	32(92)	32(92)	07-81	14.7.1.73
TM-74	Power Supply Temperature	TPST	P	32(93)	32(93)	06-90	14.7.1.74
TM-75	Band 6 Post Amp Temperature	TB6PAT	P	32(94)	32(94)	06-91	14.7.1.75
TM-76	Multiplexer Electronics Temperature	TMUXET	P	32(96)	32(96)	06-88	14.7.1.76
TM-77	Multiplexer Power Supply Temperature	TMUXPST	P	32(97)	32(97)	06-89	14.7.1.77
TM-78	Calibration Lamp Driver Temperature	TLMPDRT	P	32(95)	32(95)	06-92	14.7.1.78
TM-79	Primary Mirror Temperature	TPMT	P	32(98)	32(98)	07-89	14.7.1.79
TM-80	Primary Mirror Mask Temperature	TPMMT	P	32(99)	32(99)	07-90	14.7.1.80
TM-81	Secondary Mirror Temperature	TSMT	P	32(100)	32(100)	06-93	14.7.1.81
TM-82	Seconary Mirror Temperature	TSMMT	P	32(101)	32(101)	06-94	14.7.1.82
TM-83	Ambient Even Pre Amp Temperature	TAEPAT	P	32(102)	32(102)	07-82	14.7.1.83
TM-84	Telescope Housing Temperature	TTHT	P	32(103)	32(103)	07-91	14.7.1.84

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Table 14.7-1. IM Telemetry List

USER ID.		ACRONYM	SIG TYPE	MATRIX LOC MISSION	MATRIX LOC ENGR	RIU # - CH	REFERENCE PARAGRAPH
IM-85	Telescope Baseplate Temperature	ITBPT	P	32(104)	32(104)	07-92	14.7.1.85
IM-86	Calibration Shutter Hub Temperature	TCALSHT	P	32(79)	32(79)	07-83	14.7.1.86
IM-87	SMA +Z Housing Temperature	TDWNSMT	P	32(105)	32(105)	06-80	14.7.1.87
IM-88	SMA -Z Housing Temperature	TUPSMT	P	32(106)	32(106)	06-81	14.7.1.88
IM-89	Scan Angle Monitor Temperature	TSAMT	P	32(111)	32(111)	06-82	14.7.1.89
IM-90	SMA Electronics Temperature	TSMAET	P	32(108)	32(108)	06-83	14.7.1.90
IM-91	SMA +X Flex Pivot Temperature	TFWDSMT	P	32(109)	32(108)	06-84	14.7.1.91
IM-92	SMA -X Flex Pivot Temperature	TAFTSMT	P	32(110)	32(110)	06-85	14.7.1.92
IM-93	Sunshield Temperature	TSST	P	32(113)	32(113)	06-86	14.7.1.93
IM-94	SLC Temperature	TSLCT	P	32(112) 52	32(112)	07-84	14.7.1.94
IM-95	Calibration Lamp Filter Temperature	TLMPFT	P	32(114)	32(114)	07-85	14.7.1.95
IM-96	Cooler Ambient Stage Temperature	TCAST	P	32(115)	32(115)	07-93	14.7.1.96
IM-97	Cooler Door Temperature	TCDT	P	32(116)	32(116)	07-94	14.7.1.97
IM-98	(Function Deleted)						
IM-99	(Function Deleted)						

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Table 14.7-1. TM Telemetry List

USER ID		ACRONYM	SIG TYPE	MATRIX LOC MISSION	MATRIX LOC ENGR	RIU # - CH	REFERENCE PARAGRAPH
TM-100	+Y Radiator Fin Temperature	TRFINT	P	32(119)	32(119)	07-95	14.7.1.98
TM-101	Serial Word A	TWORDA	S	32(20)	32(20)	08-00	14.7.2.1
	Thermal Shutdown Status	TTHSDWN					14.7.2.2
	SMA Heater Controller Status	TSMASTAT					14.7.2.3
	Serial Command Receiver Status	TSCRSTAT					14.7.2.4
	Shutter Fusible Link Status	TSHRFZLK					14.7.2.5
TM-102	Serial Word B	TWORDB	S	32(21)	32(21)	08-01	14.7.2.6
	Band Status	TBNDSTAT					14.7.2.7
	Cold Stage Controller Status	TCSCNTR					14.7.2.8
TM-103	Serial Word C	TWORDC	S	32(22)	32(22)	08-02	14.7.2.9
	Door Position Monitor	TDOORPSN					14.7.2.10
	Door Electro-Magnet Status	TDOOREM					14.7.2.11
	Door Motor Status	TDOORMTR					14.7.2.12
	Door Fusible Link Status	TDRFZLK					14.7.2.13
TM-104	Serial Word D	TWORDD	S	32(23)	32(23)	08-03	14.7.2.14
	Cal Lamp Status	TLMPSTAT					14.7.2.15
	Multiplexer Status	TMUXPWR					14.7.2.16
TM-105	Serial Word E	TWORDE	S	32(24)	32(24)	08-04	14.7.2.17
	Inchworm Control and Monitor	TIWSTAT					14.7.2.18
	Blackbody Control Status	TBBSET					14.7.2.19
	Scan Mirror Electronics Status	TSMESEL					14.7.2.20
TM-106	Serial Word F	TWORDF	S	32(25)	32(25)	08-05	14.7.2.21
	Baffle Heater Control Status	TBAFFHTR					14.7.2.22
	Macro Discrete Cmd Gen Selection	TMCGSEL					14.7.2.23
	Multiplexer Status	TMUXPWR					14.7.2.16
	Mid Scan Marker Select	TMIDSCAN					14.7.2.24

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Table 14.7-1. TM Telemetry List

USER ID		ACRONYM	SIG TYPE	MATRIX LOC MISSION	ENGR	RIU # - CH	REFERENCE PARAGRAPH
TM-107	Serial Word G	TWORDG	S	32(26)	32(26)	08-06	14.7.2.25
	Scan Line Corrector Status	TSLCSEL					14.7.2.26
	Calibration Shutter Status	TCALSHTR					14.7.2.27
	Backup Shutter Status	TBUSHTR					14.7.2.28
TM-108	Serial Word H	TWORDH	S	32(27)	32(27)	08-07	14.7.2.29
	Cold Stage Controller Status	TCSCNTRL					14.7.2.8
	Intermediate Stage Controller Statusq	TISCNTRL					14.7.2.30
	CFPA Temperature Control Status	TCFPA					14.7.2.31
TM-109	Serial Word I	TWORDI	S	32(28)	32(28)	08-08	14.7.2.32
TM-110	Serial Word J	TWORDJ	S	32(29)	32(29)	08-09	14.7.2.33
	Command Echo	TECHO					14.7.2.34
TM-111	Serial Word K	TWORDK	S	75		08-10	14.7.2.35
TM-112	Serial Word L	TWORDL	S	32(30)	32(30)	08-11	14.7.2.36
	DC Restore Status	TDCRSTAT					14.7.2.37
	ILM Scaling and DCR Status	TILMSCAL					14.7.2.38
	SMA Heater Controller Status	TSMASTAT					14.7.2.3
	Mid Scan Marker Status	TMIDSCAN					14.7.2.24
	Scan Mirror Control Status	TSAMSEL					14.7.2.39

14.7.1.2 Power Supply #2 Input Current (TM-02)

This telemetry function monitors the input current being drawn by power supply number 2. The telemetry signal is derived by sensing the voltage drop across a resistor in the input power return line and conditioning it to match the telemetry range. The telemetry derivation circuit appears as Figure 14.7-1. Operating limits for this function is in Table 14.7-2.

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Table 14.7-2. TM Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Upper	E.U. Units
TM-01	TMPS1I	PS1 ON	1.0	16.0	AMPS
TM-02	TMPS2I	PS2 ON	1.0	16.0	AMPS
TM-03	TM19VP	TM ON	17.0	27.0	
TM-04	TM19VN	TM ON	-27.0	-17.0	
TM-05	TM8V		7.5	11.0	VOLTS
TM-06	TM80V	TM ON	79	107	VOLTS
TM-07	TM33V	TM ON	30	42	VOLTS
TM-08	TMLMPS	TM ON	N/A	N/A	COUNTS
TM-09	TM119VP	TM ON	17.0	27.0	VOLTS
TM-10	TM119VN	TM ON	-27.0	-17.0	VOLTS
TM-11	TM219VP	TM ON	17.0	27.0	VOLTS
TM-12	TM219VN	TM ON	-27.0	-17.0	VOLTS
TM-13	TM319VP	TM ON	17.0	27.0	VOLTS
TM-14	TM319VN	TM ON	-27.0	-17.0	VOLTS
TM-15	TM419VP	TM ON	17.0	27.0	VOLTS
TM-16	TM419VN	TM ON	-27.0	-17.0	VOLTS
TM-17	TM519VP	TM ON	17.0	27.0	VOLTS
TM-18	TM519VN	TM ON	-27.0	-17.0	VOLTS
TM-19	TM619VP	TM ON	17.0	27.0	VOLTS
TM-20	TM619VN	TM ON	-27.0	-17.0	VOLTS
TM-21	TMI19VP	TM ON	17.0	27.0	VOLTS
TM-22	TMI19VN	TM ON	-27.0	-17.0	VOLTS
TM-23	TMVU9V	TM ON	7.0	9.0	VOLTS
TM-24	TM17V	PS1 ON	6.0	10.0	VOLTS
TM-25	TM127VP	PS1 ON	26.0	32.0	VOLTS
TM-26	TM127VN	PS1 ON	-32.0	-26.0	VOLTS
TM-27	TM27V	PS2 ON	6.0	10.0	VOLTS
TM-28	TM227VP	PS2 ON	26.0	32.0	VOLTS
TM-29	TM227VN	PS2 ON	-32.0	-26.0	VOLTS
TM-30	TMUX30V	MUX ON	29.0	31.0	VOLTS
TM-31	TMUXI	MUX ON	3.9	4.4	AMPS
TM-32	TBITDEN	MUX ON	0	5	# of 1's
TM-33	TMUX5VP	MUX ON	4.7	5.4	VOLTS
TM-34	TMUX18V	MUX ON	17.0	19.0	VOLTS
TM-35	TMUX3VN	MUX ON	-2.2	-1.9	VOLTS
TM-36	TMUX5VN	MUX ON	-5.7	-5.0	VOLTS
TM-37	TMUX13VN	MUX ON	-13.4	-12.2	VOLTS
TM-38	TM1ADVR	MUX ON	1.977	2.024	VOLTS
TM-39	TM2ADVR	MUX ON	1.977	2.024	VOLTS
TM-40	TM3ADVR	MUX ON	1.977	2.024	VOLTS

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Table 14.7-2. TM Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Limits Upper	E.U. Units
TM-41	TM4ADVR	MUX ON	1.977	2.024	VOLTS
TM-42	TM5ADVR	MUX ON	1.977	2.024	VOLTS
TM-43	TM7ADVR	MUX ON	1.977	2.024	VOLTS
TM-44	TMSLC1I	SLC 1 ON	-0.7	+0.7	AMPS
TM-45	TMSLC2I	SLC 2 ON	-0.7	+0.7	AMPS
TM-46	TSL115V	SLC 1 ON	-0.2	+0.2	DELTA VOLTS
TM-47	TSL15VP	SLC 1 ON	4.7	5.4	VOLTS
TM-48	TSL215V	SLC 2 ON	-0.2	+0.2	DELTA VOLTS
TM-49	TSL25VP	SLC 2 ON	4.7	5.4	VOLTS
TM-50	TMLMP1I	LMP 1A LMP 1BU	0	110	mAMPS
TM-51	TMLMP2I	LMP 2A LMP 2BU	0 0	110 110	mAMPS
TM-52	TMLMP3I	LMP 3A LMP 3BU	0 0	110 110	mAMPS
TM-53	TBBHTRI TBBHTRI1	BB NORM	0 70	135 82	mAmps
TM-54	TBFHTRI TBFHTRI1	 BB B/U	0 180	630 220	 mAmps
TM-55	TCSHTRI TCSHTRI1	CS B/U CS ENA	0 0	350 60	mAmps
TM-56	TIW1POS	LVPT ON	-	-	MICRO INCHES
TM-57	TIW2POS	LVDT ON	-	-	MICRO INCHES
TM-58	TIW3POS	LVDT ON	-	-	MICRO INCHES
TM-59	TBBT	TLM SCAL ON	18	50	^{o}C
TM-60	TS1FPT	TLM SCAL ON	10	40	^{o}C
TM-61	TCALST	DCR ON	0	35	^{o}C
TM-62	TBUST	DCR ON	0	35	^{o}C
TM-63	TCSCT	CS HTR ENA	85	323	^{o}K
TM-64	TCSHT	CS HTR ENA	85	323	^{o}K

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Table 14.7-2. TM Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Limits Upper	E.U. Units
TM-65	T1SCT	IS HTR ENA	121	126	°K
TM-66	T1SHT	IS HTR ENA	126	323	°K
TM-67	TCFPACT	CFPA HTR ENA	85	105	°K
TM-68	ICFPAHI	CFPA HTR ON	0	10	mA
TM-69	TBFFT	TLM SCAL ON	0	35	°C
	TBAFFT1	BAFF HTR ON	21	31	°C
TM-70	TCFPAMT	CFPA T189	89	91	°K
	TCFPAMT1	CFPA T2	94	96	°K
	TCFPAMT2	CFPA T3	104	106	°K
TM-71	TAOPAT	S/C ON	0	35	°C
TM-72	TCPAT	S/C ON	-10	40	°C
TM-73	TROT	S/C ON	0	40	°C
TM-74	TPST	S/C ON	0	50	°C
TM-75	TBCPAT	S/C ON	0	50	°C
TM-76	TMUXET	S/C ON	0	60	°C
TM-77	TMUXPST	S/C ON	0	60	°C
TM-78	TLMPDCT	S/C ON	0	50	°C
TM-79	TPMT	S/C ON	5	35	°C
TM-80	TPMMT	S/C ON	5	35	°C
TM-81	TSMT	S/C ON	5	35	°C
TM-82	TSMMT	S/C ON	5	35	°C
TM-83	TAEPAT	S/C ON	0	55	°C
TM-84	TTMT	S/C ON	5	35	°C
TM-85	TTBPT	S/C ON	5	35	°C
TM-86	TCALSHT	S/C ON	0	35	°C
TM-87	TDWNSMT	S/C ON	15	35	°C
TM-88	TUPSMT	S/C ON	15	35	°C
TM-89	TSAMT	S/C ON	5	40	°C
TM-90	TSMAET	S/C ON	5	40	°C
TM-91	TFWDSMT	S/C ON	15	35	°C
TM-92	TAFTSMT	S/C ON	15	35	°C
TM-93	TSST	S/C ON	10	22	°C
TM-94	TSLCT	S/C ON	5	40	°C
TM-95	TLMPFT	S/C ON	0	55	°C

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Table 14.7-2. TM Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Limits Upper	E.U. Units
TM-96	TCAST	S/C ON	-10	22	°C
TM-97	TCDT	S/C ON	-40	-	°C
TM-98	-	-	-	-	-
TM-99	-	-	-	-	-
TM-100	TRFNT	S/C ON	-20	25	°C

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14.7.1.3 +19V High Current Supply Monitor (TM-03)

This telemetry function monitors the voltage of the +19 volt radiometer bus. This bus is created by diode or-ing the high current +19 volt outputs of power supplies 1 and 2. The telemetry signal is derived from a resistive divider as shown in Figure 14.7-2. The +19 V radiometer bus powers the following circuits:

Board	Circuit
A1	Scan Line Corrector #1
A2	Scan Line Corrector #2
A3	Cal Lamps 1, 2 and 3
A4	Cold Stage Heater Controller *
	Blackbody Heater & Controller *
	Cold Focal Plane Assembly Heater & Controller *
A5	DC Restore & Shutter Temperature Telemetry
	Intermediate Stage Heater Controller
A6	Cal Shutter Logic
A7	Backup Shutter Logic
A8	Telemetry Scaling & Frame D.C. Restore
	Baffle Heater & Controller

* Also powered in standby modes.

The +19 volt high current supply monitor is valid if power supply 1 or 2 is on and should be within limits defined in Table 14.7-2.

14.7.1.4 - 19V High Current Supply Monitor (TM-04)

This telemetry function monitors the voltage of the -19 volt radiometer bus. The -19 volt bus is produced by diode "or-ing" the -19 volt high current outputs of power supplies 1 and 2. The telemetry signal is derived from a resistive divider and conditioned by an operational amplifier (see Figure 14.7-3). The -19 volt radiometer bus provides power to the circuits defined in the proceeding paragraph. The -19 volt high current telemetry is valid if power supply 1 or 2 is on and should be within the limits defined in Table 14.7-2.

14.7.1.5 +8 Volt Supply Monitor (TM-05)

This telemetry function monitors the voltage of the +8 volt bus. The bus is created by diode or-ing the +8 volt outputs of power supplies 1 and 2. The telemetry signal is derived using a resistive divider as shown in Figure 14.7-4. The 8 volt supply should be within the operating limits defined in Table 14.7-2 when either power supply 1 or 2 is on. The +8 volt bus provides logic power to the circuits listed below.

Board #	Circuit
A1	Scan Line Corrector 1
A2	Scan Line Corrector 2
A3	Inchworm Control
A6	Calibration Shutter Drive
A7	Back-up Shutter Drive
A8	Calibration Lamp
A9	Cooler Door Drive

14.7.1.6 +80 Volt Heater Supply Monitor (TM-06)

This telemetry function monitors the voltage of the +80 volt heater bus. The heater bus is created by diode or-ing the +80 volt outputs of power supplies 1 and 2. The telemetry signal is derived from resistive dividers on the combined bus as shown in Figure 14.7-5. The +80 volt bus should be within the limits defined in Table 14.7-2 if either power supply 1 or 2 is on. The +80 volt heater bus provides power to the cold stage outgas heater (board A4) and the intermediate stage outgas heater (board A5).

14.7.1.7 +33 Volt Shutter Drive Monitor (TM-07)

This telemetry function monitors the voltage of the +33v shutter drive bus. The shutter drive bus is created by diode or-ing the +33 volt outputs of power supplies 1 and 2. The telemetry signal is derived from a resistive divider at the combined bus as shown in Figure 14.7-6. The +33 volt bus should be within the limits defined in Table 14.7-2 if either power supply 1 or 2 is on. The +33 volt bus provides power to the following circuits:

Board #	Circuit
A6	Cal Shutter Drive
A7	Back-up Shutter Drive
A9	Cooler Door Motor & Brake
A14	MDCG Pulse Generators

14.7.1.8 All Cal Lamps ON Monitor (TM-08)

This telemetry function monitors the status of the calibration lamp sequencer. When the sequencer is in the all lamps on state, the telemetry value approaches 250 counts. The all cal lamps on telemetry is valid when the calibration sequencer is on. There are no limits associated with this telemetry function, however, in the automatic calibration mode this function should be "true" (ie. > 125 counts) approximately 2.86 seconds out of 22.9 seconds. The telemetry derivation circuit appears as Figure 14.7-7.

14.7.1.9 Band 1 +19 Volt Supply Monitor (TM-09)

This telemetry function monitors the voltage of the band 1 +19 volt bus. The band 1 +19 volt bus is created by diode "or-ing" the +19 volt band 1 outputs of power supplies 1 and 2. This bus provides power to the detectors, pre-amps, and post-amps associated with band 1. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when Band 1 is on and should be within the limits defined in Table 14.7-2.

14.7.1.10 Band 1 -19 volt Supply Monitor (TM-10)

This telemetry function monitors the voltage of the band 1 -19 volt bus. The band 1 -19 volt bus is created by diode "or-ing" the -19 volt band 1 outputs of power supplies 1 and 2. This bus provides power to the detectors, pre-amps and post-amps associated with band 1. The telemetry signal is derived from a resistive divider between the -19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-9. The telemetry signal is valid when band 1 is on and should be within the limits defined in Table 14.7-2.

14.7.1.11 Band 2 +19 volt supply monitor (TM-11)

This telemetry function monitors the voltage of the band 2 +19 volt bus. The band 2 +19 volt bus is created by diode "or-ing" the +19 volt band 2 outputs of power supplies 1 and 2. This bus provides power to the detectors, pre-amps, and post-amps associated with band 2. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 2 is on and should be within the limits defined in Table 14.7-2.

14.7.1.12 Band 2 -19 volt Supply Monitor (TM-12)

This telemetry function monitors the voltage of the band 2 -19 volt bus. The band 2 outputs of power supplies 1 and 2. This bus provides power to the detectors, pre-amps, and post-amps associated with band 2. The telemetry signal is derived from a resistive divider between the -19 volt bus and return and is conditioned by and operational amplifier as shown in Figure 14.7-9. The telemetry signal is valid when band 2 is on and should be within the limits defined in Table 14.7-2.

14.7.1.13 Band 3 +19 Volt Supply Monitor (TM-13)

This telemetry function monitors the voltage of the band 3 +19 volt bus. The band 3 +19 volt bus is created by diode "or-ing" the +19 volt band 3 outputs of power supplies 1 and 2. This bus provides power to the detectors, pre-amps, and post-amps associated with band 3. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 3 is on and should be within the limits defined in Table 14.7-1.

14.7.1.14 Band 3 -19 Volt Supply Monitor (TM-14)

This telemetry function monitors the voltage of the band 3 -19 volt bus. The band 3 -19 volt bus is created by diode "or-ing" the -19 volt band 3 outputs of power supplies 1 and 2. This bus provides power to the detectors, pre-amps, and post-amps associated with band 3. The telemetry signal is derived from a resistive divider between the -19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 3 is on and should be within the limits defined in Table 14.7-1.

14.7.1.15 Band 4 +19 Volt Supply Monitor (TM-15)

This telemetry function monitors the voltage of the band 4 +19 volt bus. The band 4 +19 volt bus is created by diode "or-ing" the +19 volt band 4 outputs of power supplies 1 and 2. This bus provides power to the detectors, pre-amps, and post-amps associated with band 4. The telemetry signal is derived from band 4. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 4 is on and should be within the limits defined in Table 14.7-2.

14.7.1.16 Band 4 -19 Volt Supply Monitor (TM-16)

This telemetry function monitors the voltage of the band 4 -19 volt bus. The band 4 +19 volt bus is created by diode "or-ing" the -19 volt band 4 outputs of power supplies 1 and 2. This bus provides power to the detectors, pre-amps, and post-amps associated with band 4. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 4 is on and should be within the limits defined in Table 14.7-2.

14.7.1.17 Band 5 +19 Volt Supply Monitor (TM-17)

This telemetry function monitors the voltage of the band 5 -19 volt bus. The band 5 +19 volt bus is created by diode "or-ing" the +19 volt band 5 outputs of power supplies 1 and 2. This supply provides power to the detectors pre-amps, and post-amps associated with band 5. The telemetry signal is derived from band 5 and 7. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 5 is on and should be within the limits defined in Table 14.7-2.

14.7.1.18 Band 5 -19 Volt Supply Monitor (TM-18)

This telemetry function monitors the voltage of the band 5 -19 volt bus. The band 5 +19 volt bus is created by diode "or-ing" the -19 volt band 5 outputs of power supplies 1 and 2. This supply provides power to the detectors, pre-amps, and post-amps associated with band 5. The telemetry signal is derived from band 5 and 7. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 5 is on and should be within the limits defined in Table 14.7-2.

14.7.1.19 Band 6 +19 Volt Supply Monitor (TM-19)

This telemetry function monitors the voltage of the band 6 +19 volt bus. The band 6 +19 volt bus is created by diode "or-ing" the +19 volt band 4 outputs of power supplies 1 and 2. This supply provides power to the detectors, pre-amps, and post-amps associated with band 6. The telemetry signal is derived from band 6. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 6 is on and should be within the limits defined in Table 14.7-2.

14.7.1.20 Band 6 -19 Volt Supply Monitor (TM-20)

This telemetry function monitors the voltage of the band 6 +19 volt bus. The band 6 +19 volt bus is created by diode "or-ing" the +19 volt band 4 outputs of power supplies 1 and 2. This supply provides power to the detectors pre-amps, and post-amps associated with band 6. The telemetry signal is derived from band 6. The telemetry signal is derived from a resistive divider between the +19 volt bus and return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid when band 6 is on and should be within the limits defined in Table 14.7-2.

14.7.1.21 ISO +19 Volt Supply Monitor (TM-21)

This telemetry function monitors the voltage of the Scan Mirror Assembly +19 volt bus. The bus is created by diode or-ing the +19 volt SMA output of power supplies 1 and 2. The SMA +19 volt bus powers the SMA heater central circuits. The telemetry signal is derived using a resistor divider +19 volt bus and its return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid whenever the SMA heater control power is on and should be within the limits defined in Table 14.7-2. The telemetry response curve appears as Table 14.7.4-8.

14.7.1.22 ISO -19 Volt Supply Monitor (TM-22)

This telemetry function monitors the voltage of the Scan Mirror Assembly -19 volt bus. The bus is created by diode or-ing the -19 volt SMA output of power supplies 1 and 2. The SMA -19 volt bus powers the SMA heater central circuits. The telemetry signal is derived using a resistor divider -19 volt bus and its return and is conditioned by an operational amplifier as shown in Figure 14.7-8. The telemetry signal is valid whenever the SMA heater control power is on and should be within the limits defined in Table 14.7-2.

14.7.1.23 CDVU +9 Volt Monitor (TM-23)

This telemetry function monitors the voltage of the +9V CDVU bus. The CDVU bus is created by diode "or-ing" the +9 volt CDVU output of power supplies 1 and 2 mini-switchers. This bus provides power to the serial command receiver/decoder (A10), the verification register unit (A11), the macro-discrete command generator (A14), and serial digital telemetry sensing circuits (A22). The telemetry is derived from a resistive divider at the +9 volt bus as shown in Figure 14.7-10. The CDVU monitor is valid if either power supply 1 or 2 is on and should be within the limits defined in Table 14.7-2.

14.7.1.24 Power Supply #1 SMA +6.8V Monitor (TM-24)

This telemetry function monitors the voltage of the +6.8V Scan Mirror Assembly (SMA) output of power supply 1. The +6.8 volt output is diode "or-ed" with the +6.8 volt output of power supply 2 from the SMA 6.8 volt bus which provides power to the scan mirror assembly. The telemetry voltage is derived from a voltage divider across the output of 6.8 volt supply. The telemetry function should be within the operating range if power supply #1 is ON. The telemetry derivation circuit appears as Figure 14.7-11 and the operating limiting appear in Table 14.7-2.

14.7.1.25 Power Supply #1 SMA +27V Monitor (TM-25)

This telemetry function monitors the voltage of the +27V scan Mirror Assembly (SMA) output of power supply #1. The SMA +27 volt output of power supply #1 is diode "or-ed" with the +27V output of power supply 2 to form the SMA +27V bus which provides power to both scan mirror electronics and scan angle monitors. The telemetry voltage is derived by a reisistive divider across the +27 volt bus. Telemetry voltage should be within the operating range whenever power supply #1 is operating. The operating limits appear in Table 14.7-2.

14.7.1.26 Power Supply #1 SMA -27V Monitor (TM-27)

This telemetry function monitors the -27 volt Scan Mirror Assembly (SMA) output of power supply #1. The -27 volt output of power supply 1 is diode or-ed with that of power supply 2 to form the -27 volt SMA bus which provides power to the scan mirror electronics and scan angle monitor circuitry. The telemetry voltage is derived from a voltage divider at the -27 volt bus and conditioned by an amplifier having a gain of minus one. The telemetry derivation circuit appears as Figure 14.7-12. Operating limits appear in Table 14.7-2. This telemetry function should be within the operating range when power supply #1 is on.

14.7.1.27 Power Supply #2 SMA 6.8V Monito (TM-27)

This telemetry function monitors the +6.8 volt Scan Mirror Assembly (SMA) output of power supply #2. The +6.8 volt output of power supply 2 is diode or-ed with that of power supply 1 to form the SMA +6.8 volt bus which provides power to the scan mirror electronics and scan angle monitor circuitry. The telemetry voltage is derived from a resistive divider on the +6.8 volt bus. This telemetry derivation circuit appears as Figure 14.7-11. The operating limits are listed in Table 14.7-2. The telemetry voltage should be in range whenever power supply 2 is on.

14.7.1.28 Power Supply #2 SMA +27V Monitor (TM-28)

This telemetry function monitors the +27 volt SMA output of power supply #2. The +27V SMA output of power supply 2 is diode or-ed with that of power supply 1 to form the SMA +27V bus which provides power to the scan mirror electronics and scan angle monitor circuitry. The telemetry voltage is derived from a resistive divider at the +27 volt bus. The telemetry derivation circuit appears as Figure 14.7-12. The operating limits are listed in Table 14.7-2. This function should be within operating limits whenever power supply #2 is on.

14.7.1.29 Power Supply #2 SMA -27V Monitor (TM-29)

This telemetry function monitors the -27 volt Scan Mirror Assembly (SMA) output of power supply #2. The -27V output of power supply 2 is diode or-ed with that of power supply 1 to form the SMA -27 volt bus which provides power to the scan mirror electronics and scan angle monitor circuitry. The telemetry voltage is derived (see Figure 14.7-12) from a voltage divider at the -27 volt bus and conditioned by an amplifier (gain = -1). The telemetry should be within the operating range (see Table 14.7-2) when power supply #2 is on.

14.7.1.30 Multiplexer +30V Monitor (TM-30)

This telemetry function monitors the voltage of the multiplexer (MUX) +30 volt bus. The bus is formed by diode "or-ing" the +30 volt outputs of power supplies 1 and 2. The +30V bus provides all input power to the mux dc to dc converter. The telemetry signal is derived from a resistive divider across the 30 volt input and is conditioned by several stages of amplification, as shown in Figure 14.7-13. Two telemetry derivation circuits are provided but only one is utilized. The telemetry signal is valid if the multiplexer is on power supply 1, power supply 2 or both, and should be within the limits defined in Table 14.7-2.

14.7.1.31 Multiplexer Input Current Monitor (TM-31)

This telemetry function monitors current required by the multiplexer dc-dc converter. The telemetry signal is derived by rectifying the secondary voltage of a transformer whose primary is in series with the power switches of the diode converter (see Figure 14.7-14) The telemetry signal is valid when the multiplexer is on and should be within the limits defined in Table 14.7-2.

14.7.1.32 Multiplexer Bit Density (TM-32)

This telemetry function monitors the average number of "ones" per word occurring in the TM data output. The function is derived as shown in Figure 14.7-15. Basically, the unencoded data output of the formatter/multiplexer drives the switches producing unique outputs for the "1" and "0" state. The filter (~ 2 millisecond time constant) tends to average the output. The telemetry function is valid, and should be within the limits defined in Table 14.7-2, when the multiplexer is on.

14.7.1.33 Multiplexer +5V Supply Voltage (TM-33)

The Multiplexer +5 Volt telemetry monitors the Analog +5 volt output of the multiplexer dc to dc converter. The +5V Analog bus distributes power to the band 1 to 7 input buffer electronics. The telemetry voltage is derived from a resistive divider at the analog +5 volt bus. The telemetry function should be within range (see Table 14.7-2) when the multiplexer is on. The telemetry der'.ation circuit appears as Figure 14.7-12.

14.7.1.34 Multiplexer +18V Supply Voltage (TM-34)

This telemetry function monitors the 18.8 volt output of the multiplexer dc to dc converter. The +18 volt bus provides power to the Band 1 through 7 track and hold circuits, the analog multiplexer, and to the timing and telemetry output buffers. The telemetry signal is derived from a voltage divider on the +18.8 volt bus. The scaled voltage from the divider is conditioned by a unity gain amplifier. The deriation circuit appears in Figure 14.7.3-17. The telemetry function should be within limits (see Table 4.7-2) when the multiplexer is on.

14.7.1.35 Multiplexer -3V Supply Voltage (TM-35)

This telemetry function monitors the -2.3 volt output of the multiplexer dc to dc converter. The -2.3 volt bus is distributed to all multiplexer subassemblies except the oscillator (MX08) and powers ECL circuits. The telemetry signal is derived from the -2.3 volt bus using an amplifier to scale the voltage and impedance match the RIU input. The derivation circuit appears in Figure 14.7-18. The -2.3 volt should be within the operating limits defined in Table 14.7-2 when the multiplexer is on.

14.7.1.36 Multiplexer -5V Supply Voltage (TM-36)

This telemetry function monitors the voltage of the -5 volt digital output of the multiplexer dc to dc converter. The -5V volt bus powers all digital logic in the multiplexer and is distributed to every subassembly. The telemetry voltage is derived from the -5.2 volt bus and is scaled, using an operational amplifier to be compatible with the RIU. The telemetry derivation circuit appears in Figure 14.7-19. The -5 volt monitor should be within the operating range defined in Table 14.7-2 whenever the multiplexer is on.

14.7.1.37 Multiplexer -15V Supply Voltage (TM-37)

This telemetry function monitors the -13 volt output of the multiplexer dc to dc converter. The -13 volt bus is distributed to the band 1 to 7 electronics where it provides power for the A/D voltage reference circuit. The telemetry voltage is derived from the -13 volt bus using an amplifier to scale the voltage level and impedence match the RIU. The telemetry derivation circuit appears in Figure 14.7-20. The telemetry monitor should be within the limits defined in Table 14.7-2 when the multiplexer is on.

14.7.1.38 Band 1 A/D Reference Voltage (TM-38)

This telemetry monitors the output of the Band 1 A/D reference voltage generator. The 2 volt output is used as the comparison voltage for A/D conversion (225 counts = 2 volts). The telemetry voltage is derived by sensing directly, thru current limiting resistors, the reference voltage bus. The telemetry derivation circuit appears as Figure 14.7-21. The reference voltage is derived using the ±5.2 volt analog and -13 volt outputs of the multiplexer dc to dc converter and hence the telemetry monitor should be within operating limits (see Table 14.7-2) when the multiplexer is on.

14.7.1.39 Band 2 A/D reference Voltage (TM-39)

This telemetry monitors the output of the Band 2 A/D reference voltage generator. The 2 volt output is used as the comparison voltage for A/D conversion (225 counts = 2 volts). The telemetry voltage is derived by sensing directly, through current limiting resistors, the reference voltage bus. The telemetry derivation circuit appears as Figure 14.7-21. The reference voltage is derived using the ±5.2 volt analog and -13 volt outputs of the multiplexer dc to dc converter and hence the telemetry monitor should be within operating limits (see Table 14.7-2) when the multiplexer is on.

14.7.1.40 Band 3 A/D Reference Voltage (TM-40)

This telemetry monitors the output of the Band 3 A/D reference voltage generator. The 2 volt output is used as the comparison voltage for A/D conversion (225 counts = 2 volts). The telemetry voltage is derived by sensing directly, through current limiting resistors, the reference voltage bus. The telemetry derivation circuit appears as Figure 14.7-21. The reference voltage is derived using the +5.2 volt analog and -13 volt outputs of the multiplexer dc to dc converter and hence the telemetry monitor should be within operating limits (see Table 14.7-2) when the multiplexer is on.

14.7.1.41 Band 4 A/D Reference Voltage (TM-41)

This telemetry monitors the output of the Band 4 A/D reference voltage generator. The 2 volt output is used as the comparison voltage for A/D conversion (225 counts = 2 volts). The telemetry voltage is derived by sensing directly, through current limiting resistors, the reference voltage bus. The telemetry derivation circuit appears as Figure 14.7-21. The reference voltage is derived using the +5.2 volt analog and -13 volt outputs of the multiplexer dc to dc converter and hence the telemetry monitor should be within operating limits (see Table 14.7-2) when the multiplexer is on.

14.7.1.42 Band 5 A/D Reference Voltage (TM-42)

This telemetry monitors the output of the Band 5 A/D reference voltage generator. The 2 volt output is used as the comparison voltage for A/D conversion (225 counts = 2 volts). The telemetry voltage is derived by sensing directly, through current limiting resistors, the reference voltage bus. The telemetry derivation circuit appears as Figure 14.7-21. The reference voltage is derived using the +5.2 volt analog and -13 volt outputs of the multiplexer dc to dc converter and hence the telemetry monitor should be within operating limits (see Table 14.7-2) when the multiplexer is on. The Band 6 A/D conversions are performed by the Band 5 A/D converter.

14.7.1.43 Band 7 A/D Reference Voltage (TM-43)

This telemetry monitors the output of the Band 7 A/D reference voltage generator. The 2 volt output is used as the comparison voltage for A/D conversion (225 counts = 2 volts). The telemetry voltage is derived by sensing directly, through current limiting resistors, the reference voltage bus. The telemetry derivation circuit appears as Figure 14.7-21. The reference voltage is derived using the +5.2 volt analog and -13 volt outputs of the multiplexer dc to dc converter and hence the telemetry monitor should be within operating limits (see Table 14.7-2) when the multiplexer is on.

14.7.1.44 SLC 1 Drive Current (TM-44)

This telemetry function monitors the current in the Scan Line Corrector (SLC) motor return to SLC #1 electronics. The telemetry is derived by sensing the voltage drop across a 1 ohm resistor in the motor return line. The voltage drop is scaled and offset by a operational amplifier. The telemetry derivation circuit appears as Figure 14.7-22. The SLC #1 current should be within its operating range (see Table 14.7-2) when scan line corrector 1 is on.

14.7.1.45 SLC 2 Drive Current (TM. 45)

This telemetry function monitors the current in the Scan Line Corrector (SLC) motor return to SLC #2 electronics. The telemetry is derived by sensing the voltage drop across a 1 ohm resistor in the motor return line. The voltage drop is scaled and offset by an operational amplifier. The telemetry derivation circuit appears as Figure 14.7-22. The SLC #2 current should be within its operating range (see Table 14.7-2) when scan line corrector 2 is on.

14.7.1.46 SLC #1 +15V Volt Monitor (TM-46)

This telemetry function monitors the combined deviation of the plus and minus 15 volt signal buses associated with scan line corrector (SLC) electronics #1. The telemetry signal is derived from a resistive divider from the plus to minus 15 volt signal bus as shown in Figure 14.7-22. A change in telemetry voltage indicates a change in either the +15 or -15 volt buses or both. The telemetry signal is always valid and should be within the limits defined in Table 14.7-2 when SLC #1 is ON.

14.7.1.47 SLC #1 +5 Volt Monitor (TM-47)

This telemetry function monitors the scan line corrector (SLC) #1 +5 volt bus. The +5 volt bus is derived from the TM +8 volt bus. The telemetry signal is derived from a resistive divider as shown in Figure 14.7-24. The telemetry signal is always valid and should be within the operating limits defined in Table 14.7-2 when SLC #1 is ON.

14.7.1.48 SLC #2 +15V Volt Monitor (TM-48)

This telemetry function monitors the combined deviation of the plus and minus 15 volt signal buses associated with scan line corrector (SLC) electronics #2. The telemetry signal is derived from a resistive divider from the plus to minus 15 volt signal bus as shown in Figure 14.7-23. A change in telemetry voltage indicates a change in either the +15 or -15 volt buses or both. The telemetry signal is always valid and should be within the limits defined in Table 14.7-2 when SLC #2 is ON.

14.7.1.49 SLC #2 +5V Volt Monitor (TM-49)

This telemetry function monitors the scan line corrector (SLC) #2 +5 volt bus. The +5 volt bus is derived from the TM +8 volt bus. The telemetry signal is derived from a resistive divider as shown in Figure 14.7-24. The telemetry signal is always valid and should be within the operating limits defined in Table 14.7-2 when SLC #2 is ON.

14.7.1.50 Calibration Lamp 1 Current Monitor (TM-50)

This telemetry function monitors the current flowing in the calibration lamp return circuit. Each calibration lamp can operate in a normal or backup mode. In the normal mode, the lamp is on unless turned off by the sequencer and it output is controlled by a light sensitive diode in the feedback loop. In the back-up mode, the lamp is controlled by command and its output is not actively controlled. The telemetry voltage is derived from a resistor in the lamp return path. The voltage is scaled by resistive divider and the output is protected by back-to-back current limiting diodes. The telemetry derivation circuit appears as Figure 14.7-25. The calibration lamp has several operating modes. The limits for those modes appears in Table 14.7-2.

14.7.1.51 Calibration Lamp 2 Current Monitor (TM-51)

This telemetry function monitors the current flowing in the calibration lamp return circuit. Each calibration lamp can operate in a normal or backup mode. In the normal mode, the lamp is on unless turned off by the sequencer and its output is controlled by a light sensitive diode in the feed back loop. In the back-up mode, the lamp is controlled by command and its output is not actively controlled. The telemetry voltage is derived from a resistor in the lamp return path. The voltage is scaled by resistive divider and the output is protected back-to-back current limiting diodes. The telemetry derivation circuit appears as Figure 14.7-25. The calibration lamp has several operating modes. The limits for those modes appears in Table 14.7-2.

14.7.1.52 Calibration Lamp 3 Current Monitor (TM-52)

This telemetry function monitors the current flowing in the calibration lamp return circuit. Each calibration lamp can operate in a normal or backup mode. In the normal mode, the lamp is on unless turned off by the sequencer and its output is controlled by a light sensitive diode in the feed back loop. In the back-up mode, the lamp is controlled by command and its output is not actively controlled. The telemetry voltage is derived from a resistor in the lamp return path. The voltage is scaled by resistive divider and the output is protected back-to-back current limiting diodes. The telemetry derivation circuit appears as Figure 14.7-25. The calibration lamp has several operating modes. The limits for those modes appears in Table 14.7-2.

14.7.1.53 Blackbody Heater Current Monitor (TM-53)

This telemetry function monitors the current drawn by the internal calibration blackbody heater. The blackbody is a conical cavity which is controlled at one of three selectable temperatures. This control is obtained by using a thermistor as the feedback element. The thermistor derived voltage is compared against one of three set point voltages and the difference voltage used to control the current through the 75 ohm resistive heater. In the normal operating mode the heater power is proportional to the temperature difference.

In the backup mode constant voltage is applied to the heater.

The telemetry voltage is derived from a resistor in the heater return path. The voltage drop is scaled by an operational amplifier. The telemetry circuit is protected by back-to-back current limiting diodes. The telemetry derivation circuit appears in Figure 14.7-26. The operating current limits are mode dependent and appear in Table 14.7-2.

14.7.1.54 Baffle Heater Current Monitor (TM-54)

This telemetry function monitors the current flowing in the baffle heater. The heater is a thermostatically controlled 36 ohm resistive heater located on the central baffle of the telescope. The heater has two modes of operation when enabled. In the normal mode, the baffle temperature is monitored by a thermistor whose voltage is compared to a preset value equivalent to 26.6°C. If the temperature is less than the set point, the comparator "turns on" the heater. In the back-up mode the heater is continually powered at about 1.4 watts. Baffle heater current telemetry is derived from a resistor in the heater return line. The voltage drop across the resistor is scaled by a operational amplifier. The telemtrry output is protected by back-to-back current limiting diodes. The telemetry derivation circuit appears in Figure 14.7-27. The heater current should be within the modally determined limits defined in Table 14.7-2. The baffle heater current monitor is valid when the baffle heater control is on.

14.7.1.55 Cold Stage Heater Current Monitor (TM-55)

This telemetry function monitors the current flowing in the Cold Stage Heater. The heater has three operational modes: OFF, BACKUP, and OUTGAS. When the outgas heater is OFF, no current flows in the heater. In the OUTGAS mode the heater is powered from the 80 volt bus and the cold stage temperature is controlled at approximately 20°C. In the BACK UP mode the heater is powered by 15 volts which is derived from the +19 volt bus and the cold stage temperature is controlled at 105° Kelvin. The telemetry signal is derived by sensing the voltage drop across a resistor in the heater return line. The voltage is scaled as shown in Figure 14.7-28 to be compatible with the telemetry system. The current telemetry is valid when the controller is in the OUTGAS or BACKUP mode and should be within the limits defined in Table 14.7-2.

14.7.1.56 Inchworm #1 Position Monitor (TM-56)

This telemetry function monitors the position of inchworm #1. Three symmetrically located inchworms control the position of the spherical element of the relay optics (i.e., the focus and alignment of the cold focal plan to the primary focal plane). Three Linear Variable Differential Transformers (LVDT's) monitor the relative positions of the inchworms. The telemetry signal is derived using an LVDT and conditioning its output as shown in Figure 14.7-29. The telemetry signal is valid when the LVDT's are ON. The inchworms should remain in position unless commanded to move.

14.7.1.57 Inchworm #2 Position Monitor (TM-57)

This telemetry function monitors the position of inchworm #2. Three symmetrically located inchworms control the position of the spherical element of the relay optics (i.e., the focus and alignment of the cold focal plane to the primary focal plane). Three Linear Variable Differential Transformers (LVDT's) monitor the relative positions of the inchworms. The telemetry signal is derived using an LVDT and conditioning its output as shown in Figure 14.7-29. The telemetry signal is valid when the LVDT's are ON. The inchworms should remain in position unless commanded to move.

14.7.1.58 Inchworm #3 Position Monitor (TM-58)

This telemetry function monitors the position of inchworm #3. Three symmetrically located inchworms control the position of the spherical element of the relay optics (i.e., the focus and alignment of the cold focal plane to the primary focal plane). Three Linear Variable Differential Transformers (LVDT's) monitor the relative positions of the inchworms. The telemetry signal is derived using an LVDT and conditioning its output as shown in Figure 14.7-29. The telemetry signal is valid when the LVDT's are ON. The inchworms should remain in position unless commanded to move.

14.7.1.59 Blackbody Temperature Monitor (TM-59)

This function monitors the temperature of the Band 6 calibration blackbody. The telemetry is derived from a thermistor mounted on the blackbody. The thermistor is used in a voltage divider as shown in Figure 14.7-30. The divider output is scaled by an operational amplifier. The temperature of the blackbody is controlled at one of three set points (24^{o}, 30^{o}, or 35^{o}C). The telemetry monitor is valid when the Telemetry scaling circuit is on and should be within the limits defined in Table 14.7-2.

14.7.1.60 Silicon Focal Plane Temperature Monitor (TM-60)

This telemetry function monitors the temperature of the prime focal plane. The 64 detectors of bands 1 through 4 are mounted to this focal plane. The temperature telemetry is derived from a thermistor located on the band 3 even-channel pre-amp assembly. The thermistor is used in a voltage divider circuit and scaled using an operational amplifier as shown in Figure 14.2-31. The Silicon Focal Plane temperature telemetry is valid when the Telemetry Scaling Circuits are on, and should be within the limit shown in Table 14.7-2.

14.7.1.61 Calibration Shutter Temperature Moniter (TM-61)

This telemetry function monitors the temperature of the calibration shutter. The telemetry is derived from a thermistor located on the calibration shutter vane. This thermistor is also used to generate the band 6 dc restore reference signal. The thermistor is utilized in a voltage divider as shown in Figure

14.7-32. The output of the divider is offset and scaled by an operational amplifier. The telemetry output is valid when the dc restore circuitry is powered, and the output should be within the operating limits defined in Table 14.7-2.

16.7.2.1.62 Back-up Shutter Temperature Monitor (TM-62)

This telemetry function monitors the temperature of the back-up shutter flag. The flag is "viewed" by the detectors during dc restore, and hence its temperature determines the dc restore level for band 6. The shutter temperature telemetry is derived from a thermistor mounted on the back-up shutter flag. The thermistor is used in a voltage divider as shown in Figure 14.7-32. The divider output is scaled by an operational amplifier. The shutter temperature telemetry is valid when dc restore is on and should be within the operating limits defined in Table 14.7-2.

14.7.1.63 Cold Stage Temperature A Monitor (TM-63)

This telemetry function monitors the temperature of the inner or cold stage of the radiative cooler. Since the cooler operates over a wide temperature range, two telemetry monitors are provided. The cold stage temperature monitor A (cold) provides increased resolution over the range 75^{o} Kelvin to 125^{o} Kelvin. Temperature telemetry is derived using a Platinum Resistance Thermometer (PRT) in a voltage divider configuration. The PRT is used as the sensing element for the cold stage temperature control loop in addition to both temperature monitors. The voltage divider output is scaled by an operational amplifier as shown in Figure 14.7-33. The cold stage temperatures are valid when the cold stage heater is enabled and should be within the operating range shown in Table 14.7-2.

14.7.1.64 Cold Stage Temperature B Monitor (TM-64)

This telemetry function monitors the temperature of the inner (cold) stage of the radiative cooler. Since the cooler operates over a large temperature range, two telemetry functions are utilized to provide the required resolution and range. A single Platinum Resistance Thermometer (PRT) is used as the temperature sensing element for thermal control of the cold stage as well as the two temperature telemetry monitors. The telemetry for the cold stage temperature B (where B is derived using a PRT, in a voltage divider. The divider output is scaled to accommodate the full temperature range. The telemetry derivation circuit appears as Figure 14.7-33. The monitor [illegible] valid when the cold stage heater is enabled and should be within the range de[illegible] in Table 14.7-2.

14.7.1.65 Intermediate Stags Temperature A Monitor (TM-65)

This telemetry function monitors the temperature of the intermediate stage of the radiative cooler. Since a wide temperature range is required two temperature monitors are provided. Monitor A, which monitors the low temperature range (125° to 170°K) with increased resolution and monitor B which monitors the entire range (100 to 320°K) but has little resolution. The telemetry voltage is derived from a Platinum Resistance Thermometer (PRT) used in a voltage divider as shown in Figure 14.7.3-34. The divider output is scaled by an operational amplifier. Since the +12 volt power required by this monitor is provided when the intermediate stage heater is enabled, the telemetry is valid only when that heater is enabled. The operating limits are provided in Table 14.7-2.

14.7.1.66 Intermediate Stags Temperature B Monitor (TM-65)

This telemetry function monitors the temperature of the intermediate stage of the radiative cooler. Since a wide temperature range is required, two temperature mMonitors are provided: onitor A, which monitors the low temperature range (125° to 170°K) with increased resolution; and monitor B, which monitors the entire range (100 to 320°K) but has little resolution. The telemetry voltage is derived from a Platinum Resistance Thermometer (PRT) used in a voltage divider as shown in Figure 14.7-34. The divider output is scaled by an operational amplifier. Since the +12 volt power required by this monitor is provided when the intermediate stage heater is enabled, the telemetry is valid only when that heater is enabled. The operations limits are provided in Table 14.7-2.

14.7.1.67 CFPA Control Temperature Monitor (TM-67)

This telemetry function monitors the temperature of the Cold Focal Plane Assembly (CFPA). This is one of two monitors performing this function. The telemetry voltage is derived from the sensing element used to control the CFPA temperature. The sensing element is a silicon diode mounted on the cold focal plane. The diode is utilized as the feedback element. The telemetry deriation circuit appears as Figure 14.7-35. The telemetry deviation circutry is powered by the +15 volt regulators associated with CFPA heater enable and hence the telemetry is valid when the CFPA heater is enabled. The CFPA temperature should be within the limits defined in Table 14.7-2 if the radiative cooler is at operating temperature.

14.7.1.68 Cold Focal Plane Assembly Heater Current Monitor (TM-68)

This telemetry function monitors the current flowing in the Cold Focal Plane Assembly (CFPA) heater The CFPA heater is a 5500 ohm deposited heater located on the back side of the CFPA substrate. The telemetry voltage is derived from the voltage drop across the CFPA heater element, and conditioned by an operational amplifier. The telemetry derivation circuit and response function appears in Figure 14.7-36. The CFPA heater current telemetry is valid when the heater controller is on and should be within the limits defined in Table 14.7-2.

14.7.1.69 Baffle Temperature Monitor (TM-69)

This telemetry function monitors the temperature of the telescope baffle. The baffle temperature telemetry is derived from a thermistor located about midway along the length of the primary mirror central baffle. The thermistor is used as one element in a voltage divider as shown in Figure 14.7-37. The output of the divider is appropriately scaled by an operational amplifier. The baffle temperature monitor circuitry is part of the temperature scaling circuit, and the output is valid when the temperature scaling circuit is on. The baffle temperature is actively controlled if the baffle heater is on and should be within the limits defined in Table 14.7-2.

14.7.1.70 CFPA Monitor Temperature Monitor (TM-70)

The CFPA monitor temperature function monitors the temperature of the Cold Focal Plane Array. The CFPA temperature is sensed by a diode mounted on the CFPA substrate. The diode is used in the feedback loop of an operational amplifier as shown in Figure 14.7-35. The CFPA is temperature is actively controlled at one heater control circuitry. Additionally, the CFPA can be controlled using the Cold Stage heater. Temperature control requires that the cold stage be at temperature. The CFPA temperature should be within the limits defined in Table 14.7-2. The CFPA monitor temperature is one of two temperature monitors on the CFPA.

14.7.1.71 Ambient Odd Pre-Amp Temperature Monitor (TM-71)

This telemetry function monitors the temperature of the pre-amplifier assembly for odd prime focal plane channels. The sensing element is a thermistor located on the band 3 assembly. The telemetry deriation circuit appears as Figure 14.7-38. The pre-amp temperature telemetry is always valid and should be within the range defined in Table 14.7-2.

14.7.1.72 Cold Pre-Amp Temperature Monitor (TM-72)

This telemetry function monitors the temperature of the pre-amplifiers on the cold focal plane assembly. The sensing element is a thermistor located on the Band 7 pre-amp assembly. The telemetry voltage is derived using the standard passive telemetry circuit in Figure 14.7-38. The telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.73 Relay Optics Temperature Monitor (TM-73)

This telemetry function monitors the temperature of the relay optics. The sensing element is a thermistor located on inchworm #1 assembly. The telemetry voltage is derived from the standard passive temperature circuit (Figure 14.7-38). The relay optics temperature telemetry is always valid and should be within the range defined in Table 14.7-2.

14.7.1.74 Power Supply Temperature Monitor (TM-74)

This telemetry function monitors the temperature of the power supply module. The sensing element is a thermistor mounted on the power supply heat sink. The thermistor is used in the standard passive temperature sensing circuit (Figure 14.7-38). The power supply temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.75 Band 6 Post-Amp Temperature Monitor (TM-75)

This telemetry function monitors the temperature of the band 6 Post-Amp. The sensing element is a thermistor located on the band 6 post-amp circuit board. The thermistor is used in the standard passive temperature telemetry circuit (Figure 14.7-38). The temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.76 Multiplexer Electronics Temperature Monitor (TM-76)

This telemetry function monitors the temperature of the multiplexer electronics the sensing element is a thermistor mounted on the NRZ-L Data Output board of the multiplexer. The passive analog telemetry circuit is shown in Figure 14.7-40. The temperature of the multiplexer electronics depends upon the status of the multiplexer and its duty cycle. The temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.77 Multiplexer Power Supply Temperature Monitor (TM-77)

This telemetry function monitors the temperature of the multiplexer power supply. The sensitive elements are two thermistors mounted on the MUX dc-dc converter. The temperature telemetry circuit is the same as that used for the mux electronics temperature and appears as Figure 14.7-40. The power supply temperature is always valid and dependant upon the status and duty cycle of the mux, but should be within the limits defined in Table 14.7-2.

14.7.1.78 Calibration Lamp Driver Temperature Monitor (TM-78)

This telemetry function monitors the temperature of the calibration lamp driver circuit board. The sensing element is a thermistor mounted on circuit card A3 in the electronics module. The telemetry deviation circuit appears as Figure 14.7-38. The calibration lamp driver temperature is alwasy valid and should be within the limits defined in Table 14.7-2.

14.7.1.79 Primary Mirror Temperature Monitor (TM-79)

This telemetry function monitors the temperature of the primary mirror. The sensing element is a thermistor mounted on the back of the telescope primary mirror. The telemetry deviation circuit appears as Figure 14.7-38. The primary mirror temperature is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.80 Primary Mirror Mask Temperature Monitor (TM-80)

This telemetry function monitors the temperature of the primary mirror mask. The sensing element is a thermistor located on the back of the primary mirror mask. The telemetry deviation circuit appears as Figure 14.7-38. The primary mirror mask temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.81 Secondary Mirror Temperature Monitor (TM-81)

This telemetry function monitors the temperature of the secondary mirror. The sensor is a thermistor mounted on the back of the secondary mirror support plate. The telemetry derivation circuit appears as Figure 14.7-38. The secondary mirror temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.82 Secondary Mirror Mask Temperature Monitor (TM-82)

This telemetry function monitors the temperature of the secondary mirror mask. The sensing element is a thermistor located on the secondary mirror mask. The telemetry derivation circuit appears as Figure 14.7-38. The secondary mirror mask temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.83 Ambient Even Preamp Temperature Monitor (TM-83)

This telemetry function monitors the temperature of the preamps associated with the even numbered preamps of the prime focal plane channels. The sensing element is a thermistor located on the band 3 assembly. The telemetry derivation circuit appears as Figures 14.7-38. The ambient even preamp temperature telemetry is always valid should be within the limits defined in Table 14.7-2.

14.7.1.84 Telescope Housing Temperature Monitor (TM-84)

This telemetry function monitors the temperature ot the telescope housing. The sensing element is a thermistor mounted to the telescope housing (aluminum honeycomb tube) midway between the primary and secondary mirrors. The telemetry derivation circuit is shown in Figure 14.7-38. Telescope Housing temperature telemetry is always valid and should be within the limits defined in Table

14.7-2.

14.7.1.85 Telescope Baseplate Temperature Monitor (TM-85)

This telemetry function monitors the telescope baseplate temperature. The sensing element is a thermistor mounted on the optical support bulkhead of the telescope main frame. The telemetry derivation circuit is shown in Figure 14.7-38 . The calibration shutter hub temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.87 SMA +Z Housing Temperature Monitor (TM-87)

This telemetry function monitors the temperature of the +Z and of the scan mirror assembly. The sensing element is a thermistor mounted to the +Z end of the scan mirror frame. The telemetry derivation circuit appears as Figure 14.7-39+Z housing temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.88 SMA -Z Housing Temperature Monitor (TM-88)

This telemetry function monitors the temperature of the -Z end of the scan mirror assembly. The sensing element is a thermistor mounted to the -Z end of the scan mirror frame. The telemetry derivation circuit is shown in Figure 14.7-39. The SMA -7 Housing temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.89 Scan Angle Monitor Temperature Monitor (TM-89)

This telemetry function monitors the temperature of the scan angle monitor electronics. The sensing element is a thermistor mounted scan angle monitor. The telemetry derivation circuit appear as Figure 14.7-39. Angle Monitor Temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.90 Scan Mirror Electronics Temperature Monitor (TM-90)

This telemetry function monitors the temperature of the scan mirror electronics. The sensing element is a thermistor mounted in the scan mirror electronics housing. The telemetry derivation circuit is shown in Figure 14.7-39. The Scan Mirror Electronics telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.91 SMA +X Flex pivot Temperature Monitor (TM-91)

This telemetry function monitors the temperature of the scan mirror +X flex pivot. The sensing element is a thermistor located on the scan mirror frame near the +X flex pivot. The telemetry derivation circuit appears as Figure 14.7-39. The +X Flex Pivot temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.92 SMA -X Flex Pivot Temperature Monitor (TM-92)

This telemetry function monitors the temperature of the -X (aft) flex pivot. The sensing element is a thermistor mounted on the scan mirror frame near the -X flex pivot. The telemetry derivation circuit is shown in Figure 14.7-39. The -X flex pivot temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.93 Sunshield Temperature Monitor (TM-93)

This telemetry function monitors the temperature of the sunshield. The sensing element is a thermistor mounted on the main frame near the sunshield. The telemetry derivation circuit is shown in Figure 14.7-38. The Sunshield Temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.94 SlC Temperature Monitor (TM-94)

This telemetry function monitors the temperature of the Scan Line Corrector (SLC). The sensing element is a thermistor located on the SLC mirror mount. The telemetry derivation circuit appears as Figure 14.7-38. The SlC temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.95 Calibration Lamp Filter Temperature Monitor (TM-95)

This telemetry function monitors the temperature of the calibration lamp filters. The sensing element is a thermistor located on the filter housing since the housing is mounted to the aft optics bulkhead it is also an indication of that item's temperature. The telemetry derivation circuit is shown in Figure 14.7-38. The filter temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.96 Cooler Ambient Stage Temperature Monitor (TM-96)

This telemetry function monitors the temperature of the ambient stage of the radiative cooler. The sensing element is a thermistor mounted on the preamplifier support ring. The telemetry derivation circuit appears as Figure 14.7-38. The Ambient Stage Temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.97 Cooler Door Temperature Monitor (TM-97)

This telemetry function monitors the temperature of the cooler door. The sensing element is a thermistor mounted on the earth facing surface of the cooler door. The telemetry derivation circuit is shown in Figure 14.7-39. The

Door Temperature telemetry is always valid and should be within the limits defined in Table 14.7-2.

14.7.1.98 +Y Radiator Fin Temperature Monitor (TM-100)

This telemtry function monitors the temperature of the +Y facing Radiator Fins. The sensing element is a thermistor mounted on one corner of the radiator. The telemetry derivation circuit is shown in Figure 14.7-38. The Fin Temperature telemetry is always valid and should be within the limits defined by Table 14.7-2.

14.7.2 TM DIGITAL TELEMETRY MONITORS

The Thematic Mapper utilizes 12 serial digital telemetry words. These digital words are of three types: bi-level status, command echo, and subcommutated diagnostics. Words A through H and L are collections of bi-level status bits. Words I and J, when combined, provide the as received serial command word 870 message. Word K is subcomutated 128 times per major frame. The first 32 words are derived by the scan mirror assembly micro-processor and provide diagnostic information. The remaining 96 words are not defined. Each serial digital word is defined in the following paragraphs. All serial telemetry requires Command and Data Verification Unit (CDVU) power and therefore, is invalid unless CDVU power is on. The typical digital word output circuit appears as Figure 14.7-41. Serial digital words are output most significant bit first (i.e. MSB = Bit 2^7 weight = S0).

14.7.2.1 Serial Digital Word A (TWORDA)

This telemetry function consists of the 8 bi-level status bits presented in telemetry word TM-101. The bits define or partially define the status of four unrelated functions. "TWORDA" is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<-------------------TM 101------------------->							
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORDA are identified as:

BIT	FUNCTION
S0	Unused Bit = 1
S1	Thermal Shutdown Enabled/Disabled
S2	SMA +Z Heater Controller Engaged/Disabled
S3	SMA -Z Heater Controller Enabled/Disabled
S4	Serial Command Receiver 1 ON/OFF
S5	Shutter Fusible Link Switch A ON/OFF
S6	Shutter Fusible Link Switch B ON/OFF
S7	Shutter Fusible Link Switch C ON/OFF

14.7.2.2 Thermal Shutdown Status (TTHSDWN)

This telemetry function monitors the status of the power supply, thermal shutdown control relay. TTHSDWN is defined as:

Bit Weight	2^0
User ID	TM101
Bit ID	S1

The event logic associated with TTHSDWN is:

Thermal Shutdown Mode	TTHSDWN State
Disabled	0
Enabled	1

The telemetry is derived as shown in Figure 14.7-42. A DISABLED status indicates that the shutdown circuit has been disconnected from the power supply. The ENABLED status indicates that the shutdown circuit is connected to the power supply control circuit. If the temperature of the switching transistors neat sink exceeds 50° centigrade, the voltage comparator trips, shutting down the power supply. As the temperature cools below 50° the power supply will automatically turn on. In the shutdown mode the CDVU +9 volt supply remains operative. TTHSDWN may be utilized in the verification of the following commands:

Command Number	Command Acronym	TTHSDWN State
736	THSDNENA	1
702	THSDNDIS	0

14.7.2.3 SMA Heater Controller Status (TSMASTAT)

This telemetry function monitors the status of the scan mirror assembly (SMA) heater controllers. TSMASTAT is defined as:

Bit Weight	2^3	2^2	2^1	2^0
User ID	TM112	TM101	TM112	TM101
Bit ID	S4	S3	S3	S2

The event logic associated with TSMASTAT is defined as:

Heater Controller Status	TSMASTAT State
Both Disabled	0 0 0 0
-Z Enabled	1 1 0 0
+ Enabled	0 0 1 1
Both Enabled	1 1 1 1

The telemetry derivaiton appears as Figure 14.7-43. Disabling a heater controller removes the input power (+19 volts) from the +12 volt regulators which power the controller. Enabling a controller applies power to the regulators. With power available the SMA temperature is monitored (thermistor) and if the temperature is less than 18^{o} centigrade (sensed by a voltage comparator) the SMA heater (nominal 20 watts each) is turned on. At 22^{o}C the heater is turned off. TSMASTAT may be utilized in the verification of following commands:

Common Number	Acronym	TSMASTAT State
871 (8000)	SMPZHTON	** 11
871 (4000)	SMPZHTOF	** 00
871 (2000)	SMPZHTON	11 **
871 (1000)	SMPZHTOF	00 **

* don't care (1 or 0)

14.7.2.4 Serial Command Receiver Status (TSCRSTAT)

This telemetry function monitors the status of the serial command receivers. TSCRSTAT as defined as:

Bit Weight	2^{0}
User ID	TM101
Bit ID	S4

The event logic associated with TSCRSTAT is defined as:

Serial Command Receiver Mode	TSCRSTAT State
#1 Selected	1
#2 Selected	0

The telemetry is derived as shown in Figure 14.7.3-44. The mode "Serial Command Receiver #1 Selected" obtains when the +9 volt CDVU power as connected to serial command receiver (SCR) 1, and logic ground is provided for command decoder number 1. SCR 1 can only be accessed from RIU 8A. The mode "Serial Command Receiver 2 selected obtain when +9 volt CDVU po\ . is applied to SCR 2 and logic ground is connect to command decoder 2. SCR 2 can only be accessed from RIU 8B. Only one command receiver/decoder can be operational at a given time.

TSCRSTAT may be utilized in the verification of the following Thematic Mapper Commands, assuming that TM is "ON":

Command #	Command Acronym	TSCRSTAT State
762	SCR1SEL	1
829	SCR2SEL	0

14.7.2.5 Shutter Fusible Link Status (TSHRFZLK)

This telemetry function monitors the status of the calibration shutter fusible link heater. TSHRFZLK is defined as:

Bit Weight	2^2	2^1	2^0
User-ID	TM101	TM101	TM101
Bit ID	S5	S6	S7

The events logic associated with TSHRP@LK is defined to be·

Shutter Fuse Link Mode	TSHRPZLK Status
Safe	0 0 0
Enabled	1 0 0
Armmed	1 1 0
Actuated	1 1 1

The telemetry is derived as shown in Figure 14.7-45. In the safe mode three commands are required to actuate the shutter fusible link heater. Enabling the shutter fusible link connects the micro-discrete command (MDC) pulse bus to the set coil of the arming relay permitting the arm command to be actuated. Arming the fusible link connects the MDC pulse bus to the set coil of the actuate relay, enabling the actuate command. Actuation connects the spacecraft bus and return to the fusible link heater. The heater softens the links and the calibration shutter is moved permanently out of the optical path.

TSHRFZLK may be used to veiify the following commands, if the Thematic Mapper is "ON".

Command Number	TSHRFZLK Acronym	Status
871 (0008)	SFLENA	100
872 (0080)	SFLARM	110
871 (0002)	SPL Fire	111
871 (0001)	FLSAFE*	000

* Partial verification see paragraph 14.7.2.13.

14.7.2.6 Serial Digital Word B (TWORDB)

This telemetry function consists of the 8 bi-level status bits contained in telemetry word TM-102. TWORD B is defined as:

Bit weight	2^7	2^6	2^5	2^{11}	2^3	2^2	2^1	2^0
User ID	<---------------TM 102----------------->							
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORD B are identified as:

BIT	FUNCTION
S0	Band 1 ON/OFF
S1	Band 2 ON/OFF
S2	Band 3 ON/OFF
S3	Band 4 ON/OFF
S4	Band 5 ON/OFF
S5	Band 6 ON/OFF
S6	Band 7 ON/OFF
S7	Cold Stage Telemetry ON/OFF

14.7.2.7 Band Status (TBNDSTAT)

This telemetry function monitors the power status of the band 1 through 7 pre and post amplifiers. TBNDSTAT is defined as:

Bit Weight	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<-------------TM 102------------>						
Bit ID	S0	S1	S2	S3	S4	S5	S6

The event logic associated with TBNDSTAT is defined as:

1. Each bit represents the power status of a band as follows:

Bit #	S0	S1	S2	S3	S4	S5	S6
Band #	1	2	3	4	5	6	7

2. A one indicates power ON a zero indicates power OFF.

3. The event name is "BANDS ON" and the mode is the list of bands identified by logic 1 status bits.

The status bits are typically derived as shown in Figure 14.7-46. A band ON status indicates that ± 19 volts have been connected to the ± 15 volt regulators that provide power to the pre and post amplifiers associated with each channel in the band. TBNDSTAT can be used to verify the following commands.

Command Number	Command Acronym	Bit #	TBNDSTAT Status
718	BD1ON	S0	1
752	BD1OFF	S0	0
754	BD2ON	S1	1
724	BDOFF	S1	0
728	BD3ON	S2	1
756	BD3OFF	S2	0
758	BD4ON	S3	1
730	BD4OFF	S3	0
819	BD5ON	S4	1
845	BD5OFF	S4	0
847	BD6ON	S5	1
825	BD6OFF	S5	0
815	BD7ON	S6	1
841	BD7OFF	S6	0

14.7.2.8 Cold Stage Heater Controller Status (TCSCNTLR)

This telemetry function monitors the status of the radiative cooler cold stage temperature controller and telemetry. TCSCNTLR is defined as:

Bit Weight	2^2	2^1	2^0
User ID	TM102	TM108	TM103
Bit ID	S7	S0	S1

The event logic associated with TCSCNTLR is defined as:

Mode	TCSCNTRL Status		
TLM ON	1	0	0
CNTLR ENA	1	1	0
OUTGAS ON	1	1	1
CNTLR DIS	0	0	0
OUTGAS ENA	0	0	1
TLM ON/OUGAS ENA	1	0	1

The status bits are derived as shown in Figure 14.7-47. The cold stage controller provides three functions: cold stage temperature telemetry, cold stage outgas heating, and a CFPA backup temperature control. The cold stage telemetry provided is a dual range temperature monitor of the cold stage temperature. The telemetry is powered whenever ± 19 volts are connected to the ± 15 volt regulators. In the outgas mode the controller maintains the cold stage temperatue at 293° K. The controller is an ON/OFF device which provides 80 volt power to the 278 ohm heater if the temperature is less than the set point. The heater controller can be used as a back-up controller for the cold focal plane temperature. For this function the controller operates in the proportional mode and utilizes 15 volt power for the 278 ohm heater.

TCSCNTLR may be used in the verification of the following commands:

Command Number	Acronym	TCSCNTLR Status
872 (8000)	CSTGTMOF	0 0 *
872 (0200)	CSTGHENA	* * 1
872 (0100)	CSTGHON	1 1 *
872 (0080)	CSTGHOFF	* 0 0

* don't care (1 or 0)

14.7.2.9 Serial Digital Word C (TWORDC)

This telemetry function is comprised of the eight bi-level status bits presented in telemetry word TM-103. The bits are all associated with the radiative cooler door. TWORD C is defined as follows:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<---------------TM 103--------------->							
Bit ID#	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORDC are:

Bit#	Name
S0	Door Closed/Not
S1	Door Outgas/Not
S2	Door Open/Not
S3	Door El tro Magnet On/Off
S4	Door Motor On/Off
S5	Door Fuse Link Switch A On/Off
S6	Door Fuse Link Switch B On/Off
S7	Door Fuse Link Switch C On/Off

14.7.2.10 Door Position Monitor (TDOORPSN)

This telemetry function monitors the position of the radiative cooler door. TDOORPSN is defined as:

Bit Weight	2^2	2^1	2^0
User ID	<---TM 103--->		
Bit ID	S0	S1	S2

The event logic associated with TDOORPSN is defined as:

Door Position Mode	TDOORPSN Status
Open	0 0 1
Outgas	0 1 0
Closed	1 0 0

The telemetry is derived as shown in Figure 14.7-48. The three positions are sensed using micro-switches. The switches are used for position control in addition to telemetry derivation. A logic one indicates that a switch is closed. The switches are located as follows: Closed-position, side of cooler enclosure, activated by side of door; outgas position, near door motor crank-arm activated by cam on the motor shaft; open position, bottom of cooler enclosure, activated by bottom edge of cooler door.

14.7.2.11 Door Electro-Magnet Status (TDOOREM)

This telemetry function monitors the status of the radiative cooler door latches. TDOOREM is defined as:

Bit Weight	2^0
User ID	TM103
Bit ID	S3

The event logic associated with TDOOREM is defined as:

Door Latch Mode	TDOOREM Status
ON	1
OFF	0

The telemetry is derived as shown in Figure 14.7-49. The door latches are two electromagnets located on the edge of the door opposite the hinge. When the door latches are ON instrument module bus power is connected to the electromagnet coils. When the door latch mode is OFF the energizing, voltage is disconnected. The door latches should be on during launch.

TDOOREM may be used to verify the following commands:

Command Number	Acronym	TCSCNTLR Status
722	DMAGON	1
732	DMAGOFF	0

14.7.2.12 Door Motor Status (TDOORMTR)

This telemetry function monitors the status of the radiative cooler door motor. TDOORMTR is defined as:

Bit Weight	2^0
User ID	TM103
Bit ID	S4

The event logic associated with TDOORMTR is defined as:

Mode	Door Motor Status	TDOORMTR
	Disabled	0
	Enabled	1

The telemetry is derived as shown in Figure 14.7-50. In the ENABLED MODE + 33 volts is connected to the motor drive and brake release circuits and +8 volt power is connected to the +5 volt regulator that supplies power to the door logic circuits. In the DISABLED MODE the +33 and +8 volt power is disconnected and the motor brake is engaged.

TDOORMTR may be used to verify the following:

Command Number	TDOORMTR Acronym	State
872(2000)	DMTROFF	0
872(4000	DMTRON	1

14.7.2.13 Cooler Door Fusible Link Status (TDRFZLK)

This telemetry function monitors the status of the radiative cooler door fusible link heater controller circuit. TDRFZLK is defined as:

Bit Weight	2^2	2^1	2^0
User ID	TM103	TM103	TM103
Bit ID	S5	S6	S7

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The event logic associated with TDRFZLK is defined as:

Door Fuse Link Mode	TDRZLK State
SAFE	000
ENABLED	100
ARMMED	110
ACTUATED	111

The telemetry is derived as shown in Figure 14.7-45. In the SAFE mode switches A, B and C are open. In the ENABLED mode, switch A is closed connecting the macro-discrete command (MDC) pulse bus to the close coil of relay (Switch) B. In the ARMMED Mode, switch B is closed connecting the MDC pulse bus to the close coil of relay (switch) C. In the ACTUATED Mode the spacecraft Bus (A/B) is connected to the fusible link heater (? ohms). As the link softens the cooler door is opened by a preloaded spring. The time required for activation is a function of voltage applied to the heater. The fusible link can be actuated only once and the resultant action (cooler door full open) is irreversible.

TDRFZLK may be used to verify the following commands:

Command Number	TDRFZLK Acronym	State
872(0040)	DFLENA	100
871(0100)	DFLARM	110
872(0010)	DFLFIRE	111

14.7.2.14 Serial Digital Word D (TWORD D)

This telemetry function is comprised of eight bilevel status bits associated with the on board calibration system and multiplex status. TWORDD is defined as:

Bit Word	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<---------------TM104--------------->							
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising word D are:

Bit	
S0	Cal Lamp 1 On/Off
S1	Cal Lamp 2 On/Off
S2	Cal Lamp 3 On/Off
S3	Cal Lamp 1 Override/Normal
S4	Cal Lamp 2 Override/Normal
S5	Cal Lamp 3 Override/Normal
S6	Lamp Sequencer On/Off
S7	Multiplexer On/Off

14.7.2.15 Calibration Lamp Status (TLMPSTAT)

This telemetry function monitors the status of the on-board calibration sources for bands 1 through 5 and 7. TLMPSTAT is defined as:

Bit Weight	S2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<---------------TM104--------------->						
Bit ID	S0	S1	S2	S3	S4	S5	S6

The event logic associated with TLMPSTAT is defined as:

Cal Lamp Mode	TLMPSTAT State						
Off	0	0	0	0	0	0	*
Auto Seq	1	1	1	0	0	0	1
Lamp 1 ON	1	0	*	*	*	*	0
Lamp 1 Backup	1	*	*	1	*	*	*
Lamp 2 ON	*	1	*	*	0	*	0
Lamp 2 Backup	*	1	*	*	1	*	*
Lamp 3 ON	*	*	1	*	*	0	0
Lamp 3 Backup	*	*	1	*	*	1	*

* don't care (or Ø)

The telemetry is derived as shown in Figure 14.7-51. In the Off Mode the ± 19 volt power to the lamps is removed and the mode control Normal/Override and sequencer On/Off relays may be either state as lamp power is not available. The automatic sequence mode requires that these lamps be on in the normal mode and the sequencer be on. Operation of each lamp is determined by the On/Off, Normal/Override and sequencer On/Off relays. The Lamp Off mode occurs when the power (± 19 volts) is removed from the control circuitry. In the normal mode the lamp is on and its output is controlled by a photodiode. In the override mode the lamp is operated at a fixed current determined by the series of resistance. If the sequencer is on, it turns all lamps in the normal mode on and off in the following sequence.

Lamp	Lamp State In Interval							
1	Off	On	On	Off	Off	On	On	Off
2	Off	Off	On	On	On	On	Off	Off
3	Off	Off	Off	Off	On	On	On	On
% Full Scale	0	20	50	30	70	90	60	40

In the override mode a lamp does not respond to sequencer commands. TLMPSTAT may be used to verify the following commands:

Command Number	Acromynn	TLMPSTAT State
738	LMP1OFF	0 0 * * * * *
708	LMP1ON	1 * * * * * *
809	LMP1OR	* 1 * * * * *
734	LMP2OFF	* * 0 0 * * *
712	LMP2ON	* * 1 * * * *
807	LMP2OR	* * * 1 * * *
714	LMP3OFF	* * * * 0 0 *
740	LMP3ON	* * * * 1 * *
833	LMP3OR	* * * * * 1 *
871(0004)	LPSEQOFF	* * * * * * 0
871(0008)	LPSEQON	* * * * * * 1

* don't care

14.7.2.16 Multiplexer Status (TMUXPWR)

This telemetry function monitors the power status of the multiplexer. TMUXPWR is defined as:

Bit Weight	2^1	2^0
User ID	TM104	TM106
Bit ID	S7	S6

The event logic associated with TMUXPWR is defined as:

Multiplexer Mode	TMUXPWR State
Off	0 0
On	1 1

The telemetry is derived as shown in Figure 14.7-52. The multiplexer can be powered by either power supply 1 or 2 or both. When +30 volts is applied to the

MUX its dc-dc converter produces seven secondary voltages. The +5.2 volt analog bus provides power for the two multiplexer on telemetry points.

14.7.2.17 Serial Telemetry Word E (TWORDE)

This telemetry function is comprised of eight bilevel status bits associated with inchworm control and monitoring, blackbody temperature control and scan mirror electronics status. TWORDE is defined as:

Bit Word	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<---------------TM105--------------->							
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising word E are:

Bit #	Function
S0	Inchworm Power On/Off
S1	LVDT On/Off
S2	Blackbody On/Off
S3	Blackbody T2 On/Off
S4	Blackbody T3 On/Off
S5	Blackbody Backup On/Off
S6	Scan Mirror Electronics 1 On/Off
S7	Scan Mirror Electronics 2 On/Off

14.7.2.18 Inchworm Control and Monitor Status (TIWSTAT)

This telemetry function monitors the status of inchworm power annd position monitoring. TIWSTAT is defined as:

Bit Weight	2^1	2^0
User ID	TM105	TM105
Bit ID	S0	S1

The event logic associated with TIWSTAT is:

Inchworm Mode	TIWSTAT State
Off	0 0
TLM On	0 1
Power On	1 0
Pwr & TLM On	1 1

The telemetry is derived as shown in Figure 14.7-53. In the power on mode +30 volts is applied to the inchworm high voltage power supplies and +8 volts is applied to the inchworm control logic. In the telemetry on mode ±19 volt power is applied to position sensing circuit which utilized linear variable differential transformers (LVDT). In the off mode all voltages are disconnected.

TIWSTAT may be used in verification of the following commands:

Command Number	Command Acronym	TIWSTAT State
872(0004)	LVDT Off	* 0
872(0020)	LVDT On	* 1
871(0001)	Inch Off	0 *
871(0002)	Inch On	1 *

* don't care (1 or 0)

14.7.2.19 Blackbody Temperature Control Status (TBBSET)

This telemetry function monitors the status of the on board calibration system blackbody temperature control circuitry. TBBSET is defined as:

Bit Weight	2^3	2^2	2^1	2^0
User ID	<-----TM105----->			
Bit ID	S2	S3	S4	S5

The event logic associated with TBBSET is:

Blackbody Control Mode	TBBSET State
Off	0 0 0 0
On T1	1 0 0 0
On T2	1 1 0 0
On T3	1 * 1 0
On Backup	1 * * 1

* don't care

The telemetry is derived as shown in Figure 14.7-54. In the Off Mode, the ± 19 volts which provides the power for the blackbody heater and controller is disconnected. In the On T1 Mode ± 19 volts is connected to the ± 12 volt regulator which provides all required power. The temperature set point relays are reset to provide a control temperature of 24°C. The On T3 mode is also similar to On T1 but results in a control temperature of 30°C. The On T2 mode is similar to On T1 is set, resulting in a control temperature of 35°C. The T3 relay overrides the T2 relay. In the On Backup mode, the temperature controller is removed and the heater runs in the constant current mode.

TBBSET may be used in the verification of the following commands:

Command Number	Acronym	TBBSET State
716	BBHTRON	1 0 0 *
746	BBHTROFF	0 0 0 0
813	BBT2SEC	1 1 0 * (1)
817	BBBKUPON	1 * * 1 (1)
835	BBT3SEC	1 * 1 * (1)

* don't care (1 or 0)
(1) requires BB heater On

14.7.2.20 Scan Mirror Electronics Selection (TSMESEL)

This telemetry function monitors the status of the scan mirror electronics status. TSMESEL is defined as:

Bit Weight	2^1	2^0
User ID	<---TM105--->	
Bit ID	S6	S7

The event logic associated with TSMESEL is:

SME Mode	TSMESEL State
1 ON	1 0
2 On	0 1
OFF	0 0

The telemetry is derived as shown in Figure 14.7-55. Bit S6 monitors the status of scan mirror electronics (SME) number 1. A logic 1 indicates that power is applied to SME 1. A logic Ø indicates that power has been disconnnected. Bit S7 monitors the power status of SME #2. A logic 1 indicates that SME 2 is powered logic Ø indicates that power is not applied. Both SME 1 and SME 2 cannot be powered at simultaneously.

TSMESEL may be used in the verification of the following:

Command Number	Acronym	TSMESEC State
748	SME1SEL	1 0
704	SME2SEL	0 1
823	SMEOFF	0 0

14.7.2.21 Serial Telemetry Word F (TWORDF)

This telemetry function is comprised of 8 bi-level status bits associated with baffle heater control, macro-discrete command generator control, multiplexer power status, and midscan marker status is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^0	
User ID	<--------------			TM106			-------------->	
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORDF are:

Bit	Function
S0	Baffle Heater Controller On/Off
S1	Baffle Heater Backup On/Off
S2	Macrodiscrete Cmd Generator A Prime On/Off
S3	Macrodiscrete Cmd Generator A Redundant On/Off
S4	Macrodiscrete Cmd Generator B Prime On/Off
S5	Macrodiscrete Cmd Generator B Redundant On/Off
S6	Multiplexer On/Off
S7	Midscan Pulse On/Off

14.7.2.22 Baffle Heater Controller Status (TBAFFHTR)

This telemetry function monitors the status of the baffle heater controller. TBAFFHTR is defined as:

Bit Weight	2^1	2^0
User ID	TM106	TM106
Bit ID	S0	S1

The event logic associated with TBFFHTR is:

Baffle Heater Control Mode	TBAFFHTR State
Off	0 0
Normal	1 0
Backup	1 1

The telemetry is derived as shown in Figure 14.7-56. In the Normal Mode, ± 19 power is applied to the controller enabling the temperature sense and compare circuits. The baffle heater is turned on and off to maintain the baffle temperature at 166°C. In the Backup Mode the baffle heater is operated in the constant power mode (~4 watts). The off mode is obtained by removing ± 19 volt power and reconnecting the temperature controller.

TBAFFHTR may be used to verify the following commands.

Command Number	Acronym	TBAFFHTR State
892(1000)	BFHTRON	1 *
872(0800)	BFHTRBU	1 1
872(0400)	BFHTROFF	0 0

* don't care (1 or 0)

14.7.2.23 Macrodiscrete Command Generator Status (TMCGSEL)

This telemetry function monitors the status of the macrodiscrete command generators. TMCGSEL is defined as:

Bit Weight	2^3	2^2	2^1	2^0
User ID	<-------------	TM106	-------------	------------>
Bit ID	S2	S3	S4	S5

The event logic associated with TMCGSEL is:

Command Generator Mode	TMCGSEL State
Both Off	0 0 0 0
B Redundant	0 0 0 1
B Prime	0 0 1 0
A Redundant	0 1 0 0
Both Redundant	0 1 0 1
A Red B Prime	0 1 1 0
A Prime	1 0 0 0
A Prime B Red	1 0 0 1
Both Prime	1 0 1 0

The telemetry is derived as shown in Figure 14.7-56. Each bit of TMCGSEL defines the On (logic 1), Off (logic Ø) state of each of the four command generators. Execution of any 871 command requires that command generator A be on and execution of any 872 command requires that command generator B be on. The prime command generators can only be accessed by RIU 8A and the redundant command generators can only be accessed by RIU 8B.

TMCGSEL may be used to verify the following commands:

Command Number	Acronym	TMCGSEL State
726	MCGSELAP	1 0 * *
760	MCGSELAR	0 1 * *
821	MCGSELBP	* * 1 0
843	MCGSELBR	* * 0 1
827	MCGOFF	0 0 0 0

* don't care (1 or 0)

14.7.2.24 Midscan Marker Status (TMIDSCAN)

This telemetry function monitors the midscan marker status. TMIDSCAN is defined as:

Bit Weight	2^1	2^0
User ID	TM112	TM106
Bit ID	S5	S7

The event logic associated with TMIDSCAN is:

Midscan Mode	TMIDSCAN State
On	1 1
Off	0 0

The telemetry is derived as shown in Figure 14.7-58. The two telemetry functions monitor the output of the NAND gate which is "set" when both Midscan On commands have been received. In the On mode the Midscan code is being inserted in the video data.

14.7.2.25 Serial Telemetry Word G (TWORDG)

This telemetry function monitors this status of the scan line correctors and the oscillating shutters. TWORDG is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<------------------TM107------------------>							
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORDG are:

Bit #	Function
S0	Scan Line Corrector 1 On/Off
S1	Scan Line Corrector 2 On/Off
S2	Calibration Shutter On/Off
S3	Calibration Shutter Phase Error No/Yes
S4	Calibration Shutter Amplitude Error No/Yes
S5	Backup Shutter On/Off
S6	Backup Shutter Phase Error No/Yes
S7	Backup Shutter Amplitude Error No/Yes

14.7.2.26 Scan Line Correlator Selection (TSLCSEL)

This telemetry function monitors the status of the redundant scan line corrector (SLC) electronics. TSLCSEL is defined as:

Bit Weight	2^1	2^0
User ID	TM107	TM107
Bit ID	S0	S1

The event logic associated with TSLCSEL is:

Scan Line Corrector Mode	TSLCSEL State
Off	0 0
1 On	1 0
2 On	0 1

The telemetry is derived as shown in Figure 14.7-59. In the "1 On" mode ± 19 volts and +8 volt power is applied to SLC 1 and the motor which drives the correcting mirror assembly is connected to SLC 1 motor drive output. In the "2 On" mode power is applied to SLC 2 electronics and the SLC motor is connected to SLC 2. TSLCSEL may be used to verify the following commands:

Command Number	Acronym	TSLCSEL State
871(0040)	SLCSEL1	1 0
871(0020)	SLCSEL2	0 1
871(0010)	SLCOFF	0 0

14.7.2.27 Calibration Shutter Status (TCALSHTR)

This telemetry function monitors the status of the calibration shutter. TCALSHTR is defined as:

Bit Weight	2^2	2^1	2^0
User ID	<---TM107--->		
bit ID	S2	S3	S4

The event logic associated with TCALSHTR is:

Cal Shutter Mode	TCALSHTR State
On in error	1 0 0
Phase lock	1 1 0
Amplitude lock	1 0 1
Off	0 0 0
On-in lock	1 1 1

The telemetry derivation appears as Figure 14.7-60 TM107(S2) defines the power status of the primary calibration shutter. A logic 1 indicates that power (+8V, $\pm$19V and +33V) has been applied to the calibration shutter drive circuits. A logic zero indicates power has been removed. TM107 S3 defines the status of the phase detector. A logic 0 indicates a phase error; 1 indicates phase okay. The same logic applies to amplitude lock.

14.7.2.28 Backup Shutter Status (TBUSHTR)

This telemetry function monitors the status of the backup shutter. TBUSHTR is defined as:

Bit Weight	2^2	2^1	2^0
User ID	<---TM107--->		
Bit ID	S5	S6	S7

The event logic associated with TBUSHTR is:

Backup Shutter Mode	TBUSHTR State
Off	0 0 0
On PA error	1 0 0
.hase lock	1 0 1
Amplitude lock	1 1 0
On in lock	1 1 1

14.7.2.29 Serial Telemetry Word H (TWORDH)

This telemetry word monitors the status of the cold stage heater controller, intermediate stage heater controller, and the cold focal plane temperature controller. TWORDH is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<---------------			TM108			--------------->	
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORDH are:

Bit #	Function
S0	Cold Stage Controller On/Off
S1	Cold Stage Power Enabled/Disabled
S2	Intermediate Stage Controller On/Off
S3	Intermediate Stage Heater Enabled/Disabled
S4	CFPA Controller On/Off
S5	CPPA T2 On/Off
S6	CPPA T3 On/Off
S7	CFPA Telemetry On/Off

14.7.2.30 Intermediate Stage Controller Status (TISCNTRL)

This telemetry function monitors the status of the radiative cooler intermediate stage heater controller. TISCNTRL is defined as:

Bit Weight	2^1	2^0
User ID	<---TM108--->	
Bit ID	S2	S3

The event logic associated with TISCNTRL is:

Intermediate Stage Controller Mode	TISCNTRL State
Off	0 0
Enabled	1 0
On	1 1
Outgas Selected	0 1

The telemetry circuit appears as Figure 14.7-61. The intermediate stage controller is enabled by applying $\pm$19 volts to the $\pm$12 volt regulator. The regulator output powers the intermediate stage temperature telemetry and the On/Off controller. The intermediate stage outages heater is turned on by grounding an input to the controller which provides +80 volts to the heater. The controller then maintains the intermediate stage temperature at 20^o Centigrade.

TISCNTRL may be used to verify the following commands.

Command Number	Acronym	TISCNTRL State
871(000)	ISTGHENA	1 *
871(0400)	ISTGHON	* 1
871(0200)	ISTGHOFF	0 0

* don't care (1 or 0)

14.7.2.31 CFPA Temperature Control Status (TCFPA)

This telemetry function monitors the status of the cold focal plane assembly (CFPA) temperature control circuitry. TCFPA is defined as:

Bit Weight	2^3	2^2	2^1	2^0
User ID	<------TM108------>			
Bit ID	S4	S5	S6	S7

The event logic associated with TCFPA is:

CFPA Temp Mode	TCFPA State
Off	0 0 0 0
TLM ON	0 * * 1
Set T1	1 0 0 1
Set T2	1 1 0 1
Set T3	1 * 1 1

* don't care (1 or 0)

The TM108 (S7) bit senses the output of the ± 15 volt regulator. A logic one indicates that +15 volts is present, thus powering the CFPA control and monitor temperature circuits. A logic Ø indicates that the regulator is not powered. TM108 (S4) senses the power status of the temperature controller. A logic 1 indicates that the proportional controller is powered and controlling the CFPA temperature at one of the three set points. TM108 (S5) senses the state of the T2 set relay. A logical 1 indicates that control temperature T2 (95° Kelvin) has been selected. Selecting T2 overrides the selection of T1 but is in turn overriden by the selection of T3. TM108 (S6) monitors the state of the T3 selection relay. A logical 1 indicates that set point T3 (105° K) has been selected. Selection of set point T3 overrides T1 and T2. If neither T2 or T3 have been selected the set point is T1 (90° K). The telemetry derivation is shown in Figure 14.7-62. TCFPA may be used to verify the following commands:

Command Number	Command Acronym	TCFPA State
710	CFPAHTON	1 0 0 1
805	CFPA2SEL	* 1 * 1 (1)
811	CFPA3SEL	* * 1 1 (1)
720	CFPATMOF	0 0 0 0 (2)
744	CFPAHTOF	0 * * 1 (1)

* don't care (= 1 or Ø)
(1) telemetry power (S7) must be on for valid output
(2) If S7 = 0 all bits = 0

14.7.2.32 Serial Telemetry Word I (TWORDI)

This telemetry function in conjunction with WORDJ provides the as received status of the command "message" associated with command 870. TWORDI is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<--------------------			TM109				-------------------->
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORDI are:

TWORDI Bit #	870 Bit #	Command Received
S0	9	Inchworm Extend/Not
S1	10	Inchworm 3 Enable/Disable
S2	11	Inchworm 2 Enable/Disable
S3	12	Inchworm 1 Enable/Disable
S4	13	Cooler Door Move/Inhibit
S5	14	Cooler Door Close/Open
S6	15	Midscan Enable A
S7	16	Midscan Enable B

14.7.2.33 Serial Telemetry Word J (TWORDJ)

This telemetry function in conjunction with TWORDI provides the as received status of the "message" associated with command 870. TWORDJ is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<---------------			TM110			--------------->	
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORDJ are:

TWORDJ Bits #	870 Bit #	Command Received
S0	1	Not Used
S1	2	Not Used
S2	3	Not Used
S3	4	Not Used
S4	5	Not Used
S5	6	Not Used
S6	7	Inchworm Move/Not
S7	8	Inchworm Contract/Not

14.7.2.34 Command Echo (TECHO)

This telemetry function monitors the as received state of command 870 message. TECHO is defined as:

Bit Weight	User ID	Bit ID	870 Bit #
2^{15}	TM110	S0	1
2^{14}	TM110	S1	2
2^{13}	TM110	S2	3
2^{12}	TM110	S3	4
2^{11}	TM110	S4	5
2^{10}	TM110	S5	6
2^9	TM110	S6	7
2^8	TM110	S7	8
2^7	TM109	S0	9
2^6	TM109	S1	10
2^5	TM109	S2	11
2^4	TM109	S3	12
2^3	TM109	S4	13
2^2	TM109	S5	14
2^1	TM109	S6	15
2^0	TM109	S7	16

C-3

The telemetry derivation circuit appears as Figure 14.7-63.

14.7.2.35 Serial Digital Work K (TWORDK)

This telemetry word is subcomutated 128 to 1. The first 32 words in each telemetry major frame a'e defined. The other 98 words are undefined. Word definitions appear in the following paragraphs.

14.7.2.35.1 Word K1 - Sync

The first sample in each major frame is a unique word identify major start. This word is "TBD".

14.7.2.35.2 Word K2 - OPSTAT N

This word defines the operational status obtaining for scan N. The bit are defined in the following Table.

Bit #	
0	Scan Direction: 0 = forward, 1 = reverse
1	Circuit" 0 = SME 1, 1 = SME 2
2	Mode: 0 = SAM, 1 = Bumper
3	
4	Program ID
5	EM = 00110
6	PF = 00110
7	F1 = 00110

14.7.2.35.3 Word K3 - SCNLIN N

This word represents the scan linearity pulse frequency for scan N. The decoding of this word is to be defined.

14.7.2.35.4 Word K4 - TRNERR N

This word in concatenation with word K5 represents the turn around error for scan N. Word K4 represents the 8 most significant bits (MSB's) of the Combined word and word K5 representing the 8 least significant bits (LSB's). The MSB of the combined word (Word 4 Bit 0) is a sign bit (0 = plus, 1 = minus). The remaining 15 bits (Word K4 bit 1 through K5 bit 7) represent the magnitude of the turn around time error in the SAM mode. Positive errors are binary encoded clock pulses and negative errors are two's complement binary encoded clock pulses. Turn around error in microseconds is calculated as:

$$TRNEER = (COUNTS)_{10}(1/84.903)(16)$$

Where "COUNTS: are the decimal equivlanet of the concatenated word. Turn around time is determined by adding TRNERR to 10,719 microseconds. If the TM is in the Bumper Mode words K4 and K5 are set to zero.

14.7.2.35.5 Word K5 - TRNERR N

Word K5 represents the 8 least significant bits of turn around error for scan N. Decoding of this word is defined in the previous paragraph.

14.7.2.35.6 Word K6 - TORPLS - N

Word K6 in concatenation with word K7 represents the turn around torque pulse width for scan N. Word K6 provides the 8 MSB's with bit 0 being the most significant. Decoding of the combined word is "to be defined".

14.7.2.35.7 Word K7 - TORPLS N

Word K7 represnts the 8 least significant bits of the turn around torque pulse width for scan N. Decoding of this word is defined in the previous paragraph.

14.7.2.35.8 Word K8 SHSERR N-1

This word concatenated with word K9 represents the second half scan error for scan N-1. The most significant bit of the combined word (Word K8 bit 0) is a sign bit (0 = plus, 1 = minus). The remaining 15 bits (Word K8 bit 1 through Word K9 bit 7) represent the magnitude of the time error from midscan to end scan. Positive errors are binary encoded while negative errors are encoded as two's complement. Second half scan error in microseconds is determined by:

$$SHSERR = (COUNTS)_{10}(1/84.903)(16)$$

Where (COUNTS) is the decimal equivalent of the magnitude. The second half scan time can determined by adding the error to the nominal time of 161,165 clock pulses or 30,378.38 microseconds. When the TM is operated in the Bumper Mode, words K8 and K9 are set to zero.

14.7.2.35.9 Word K9 - SHSERR N-1

This word, when concatenated with word K8, represents the second half scan error associated with scan N-1. Word K-9 contains the 8 least significant bits of SHSERR N-1 and is decoded as defined in the previous paragraph.

14.7.2.35.10 Word K10 - FHSERR N-1

This word concatenated with word K11 represents the first half scan error for scan N-1. The most significant bit of the combined word (K10 bit 0) is a sign bit (0 = plus 1 = minus). The remaining 15 bits (K10 bit 1 through K11 bit 7) represent the magnitude of the time error from start scan to midscan. Positive errors are binary encoded and negative errors are encoded as two complements. The first half scan error in micorseconds is determined as:

$$FHSERR = (COUNTS)_{10}(1/84.903)\ (16)$$

where $(COUNTS)_{10}$ is the decimal number of clock pulses. The first half scan time can be determined by adding the error to the nominal time of 161,164 clock pulses or 30,364.82 microseconds. When the TM is operated in the Bumper Mode words K10 and K11 are set to zero.

14.7.2.35.11 Word K11 - FHSERR N-1

This word concatenated with word K10 represent the first half scan error for scan N-1. Word K11 provides the 8 least significant bits.

14.7.2.35.12 Word K12 - SUMERR N-1

This word concatenated with words K13 and K14 represents the sum of errors for scan N-1. Word K12 provides the 8 most significant bits. Decoding of the sum of errors is to be defined.

14.7.2.35.13 Word K13 - SUMERR N-1

This word, concatenated with words K12 and K14, represent the sum of errors for scan N-1. Word K13 provides the central 8 significant bits of the resulting 24 bit word. The sum of error word is decoded as defined in the preceeding paragraph.

14.7.2.35.14 Word K14 - SUMERR N-1

This word concatenated with words K12 and K13 represents the sum of errors for scan N-1. Word K14 provides the 8 least significant bits of the resultant J24 bit word. The word is decoded as defined in Paragraph 14.7.2.35.12.

14.7.2.35.15 Word K15 - SCNCTR

This word, concatenated with word K16, represents the number of scan pairs (1 forward and 1 reverse scan) since the scan mirror assembly entered the closed loop mode. The combined 16 bit word represents a binary encoded number with word K15 bit 0 being the most significant bit and word K16 bit 7 being the least significant bit. The counter increments following a reverse scan.

14.7.2.35.16 Word K16 - SCNCTR

This word concatenated with word K15 represents the number of scan pairs since the scan mirror assembly entered the closed loop mode. Decoding is defined in the preceeding paragraph.

14.7.2.35.17 Word K17 - SCANLIN N-1

This word represents the scan linearity pulse frequency for scan N-1 and is decoded as defined in Paragraph 14.7.2.35.3.

14.7.2.35.18 Word K1 - TRNERR N-1

This word, concatenated with word K19, represents the turn around time error associated with scan N-1 Word K18 provides the 8 most significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.4.

14.7.2.35.19 Word K19 - TRNERR N-1

This word concatenated with word K18 represents the turn around time error associated with scan N-1. Word K19 provides the 8 least significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.4.

14.7.2.35.20 Word 20 - TORPLS N-1

This word concatenated with word K21 represents the turn around torque pulse. Width for scan N-1. Word K20 provides the 8 most significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.6.

14.7.2.35.21 Word ?1 - TORPLS N-1

This word concatenated with word K20 represent the turn around torque pulse width for scan N-1. Word K21 provides 8 least significant of the combined word and is decoded as defined in Paragraph 14.7.2.35.6.

14.7.2.35.22 Word K22 - SHSERR N-2

This word concatenated with word K23 represents the second half scan error associated with scan N-2. Word K22 provides the 8 most significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.8.

14.7.2.35.23 Word K23 - SHSERR N-2

This word concatenated with word K22 represents the second half scan error associated with scan N-2. word K23 provides the 8 least significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.8.

14.7.2.35.24 Word K24 - FHSERR N-2

This word concatenated with word K25 represents the first half scan error associated with scan N-2. Word K24 provides the 8 most significant bits and is decoded as defined in Paragraph 14.7.2.35.10.

14.7.2.35.25 Word K25 - FHSERR N-2

This word, concatenated with word K24, represents the first half scan error associated with scan N-2. Word K25 provides the 8 least significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.10.

14.7.2.35.26 Word K26 - SUMERR N-2

This word, concatenated with words K27 and K28, represents the sum of errors for scan N-2. Word K26 provides the 8 most significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.12.

14.7.2.35.27 Word K27 - SUMERR N-2

This word, concatenated with words K26 and K28, represents the sum of errors associated with scan N-2. Word K27 provides the 8 central bits of the combined 24 bit word, and is decoded as defined in Paragraph 14.7.2.35.12.

14.7.2.35.28 Word K28 - SUMERR N-2

This word, concatenated with words K26 and K27, represents the sum of errors associated with scan N-2. Word K28 provides the 8 least significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.12.

14.7.2.35.29 Word K29 - SCNTYM N-2

This word concatenated with words K30 and K31 represents the time required for scan N-2. Word K29 provides the 8 most significant bits of the combined word. Decoding of scan time is to be defined.

14.7.2.35.30 Word K30 - SCNTYM N-2

This word concatenated with word K29 and K31 represents the scan time required for scan N-2. Word K30 provides the central 8 bits of the combined 24 bit word and is decoded as defined in the previous paragraph.

14.7.2.35.31 Word 31 - SCNTYM N-2

This word concatenated with words K29 and K30 represents the time required for scan N-2. Word K31 provides the 8 least significant bits of the combined word and is decoded as defined in Paragraph 14.7.2.35.29.

14.7.2.35.32 Word K32 - TBD

This word is undefined but determined to be "00011111" during unit testing.

14.7.2.35.33 Word K33 through K128

These words ae unused.

14.7.2.36 Serial Telemetry Word L (TWORDL)

This telemetry word monitors the status of the DC Restore Selection, Telemetry Scaling, SMA Heaters, Midscan Code and Scan Mirror Central Mode. TWORDL is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<--------------TM112-------------->							
Bit ID	S0	S1	S2	S3	S4	S5	S6	S7

The bits comprising TWORDL are:

Bit#	Function
S0	DC Restore Backup/Normal
S1	DC Restore Frame/Not
S2	Telemetry Scaling On/Off
S3	SMA +Z Heater Enabled/Disabled
S4	SMA -Z Heater Enabled/Disabled
S5	Midscan Pulse On/Off
S6	SAM to SME 1/2
S7	Spare Bit = 1

14.7.2.37 DC Restore Status (TDCRSTAT)

This telemetry function monitors the selection of DC restoration signal to be used for band 6 processing. TDCRSTAT is defined as:

Bit Weight	2^1	2^0
User ID	TM112	TM112
Bit ID	S0	S1

The event logic associated with TDCRSTAT is:

DC Restore Mode	TDCRSTAT State
Normal	0 0
Backup	1 0
Frame	* 1

* don't care (1 or 0)

The telemetry is derived as shown in Figure 14.7-60. TM112 (S1) defines the state of the Frame DCR select rely. A logic 1 indicates that the DC restoration signal is being derived from the Frame temperature. A logic zero indicates that the DC restore signal is being derived from the calibration or backup shutter temperature. TM112 (SØ) defines the state of calibration shutter/backup shutter DCR selection relay. A logic 0 indicates that the DC restoration signal is derived from the calibration shutter temperature (if Frame DCR has not been selected). A logic 1 indicates that the temperature of the backup shutter is the source of the DC restoration signal (again assuming Frame DCR has not been selected. TDCRSTAT may be utilized in the verification of the following commands.

Command Number	Command Acronym	TDCRSTAT State
706	CSHTRON	0 0
803	BUSHTRON	1 0
732	DMAGOFF	* 1

* don't care (1 or 0)

TDCRSTAT is valid only if DCR is On.

14.7.2.38 Telemetry Sealing and DC Restore Status (TTLMSCAL)

This telemetry function monitors the status of the telemetry scaling and DC restoration circuits. TTLMSCAL is defined as:

Bit Weight	2^0
User ID	TM112
Bit ID	S2

The event logic associated with TTLMSCAL is:

Telemetry Scaling & DC Restoration	TTLMSCAL State
On	1
Off	0

The telemetry is derived as shown in Figure 14.7-64. TM112 (S2) monitors the $\pm$12 volt output of the telemetry scaling regulator. A logic 1 indicates +19 volt power has been applied to telemetry scaling $\pm$12 volt rgulators and it can be assumed that the DCR $\pm$12 volt regulators are powered. A logic zero indicating that $\pm$19 volt power has been removed from the regulators.

TTLMSCAL may be used in the verification of the following commands.

Command Number	Command Acronym	TTLMSCAL State
801	TLMSCLON	1
742	DCRTMOFF	0

14.7.2.39 Scan Mirror Control Status (TSAMSEL)

This telemetry function monitors the selection status of the scan mirror control mode. TSAMSEL is defined as:

Bit Weight	2^0
User ID	TM112
Bit ID	S6

The event logic associated with TSAMSEL is:

Scan Mirror Mode	TSAMSEL State
SAM 1 to SME 1	1
SAM 2 to SME 2	0

The telemetry is derived as shown in Figure 14.7-65. TM112 (S6) defines the power state of the buffer amplifiers that supply mirror position signals to scan mirror Electronics (SME) #1. A logic 1 indicates that the buffer which provide SAM (Scan Angle Monitor) signals to SME 1 and magnetic pick-up derived signals to SME 2 have been powered. A logic zero indicates that the buffers that supply SAM derived signals to SME 2 and magnetic pick-up derived signals to SME 1 have been selected.

TSAMSEL may be utilized in the verification of the following commands.

Command Number	Command Acronym	TSAMSEL State
750	SELSAM1	1
831	SELSAM2	0

14.7.3 TM TELEMETRY DERIVATION SCHEMATICS

The following figures depict the telemetry derivation circuits referenced in the preceding paragraphs. The figures are arranged by figure number and do not have page numbers. For ease of understanding, the figures may be inserted in the appropriate locations in Paragraphs 14.7.1 and 14.7.2.

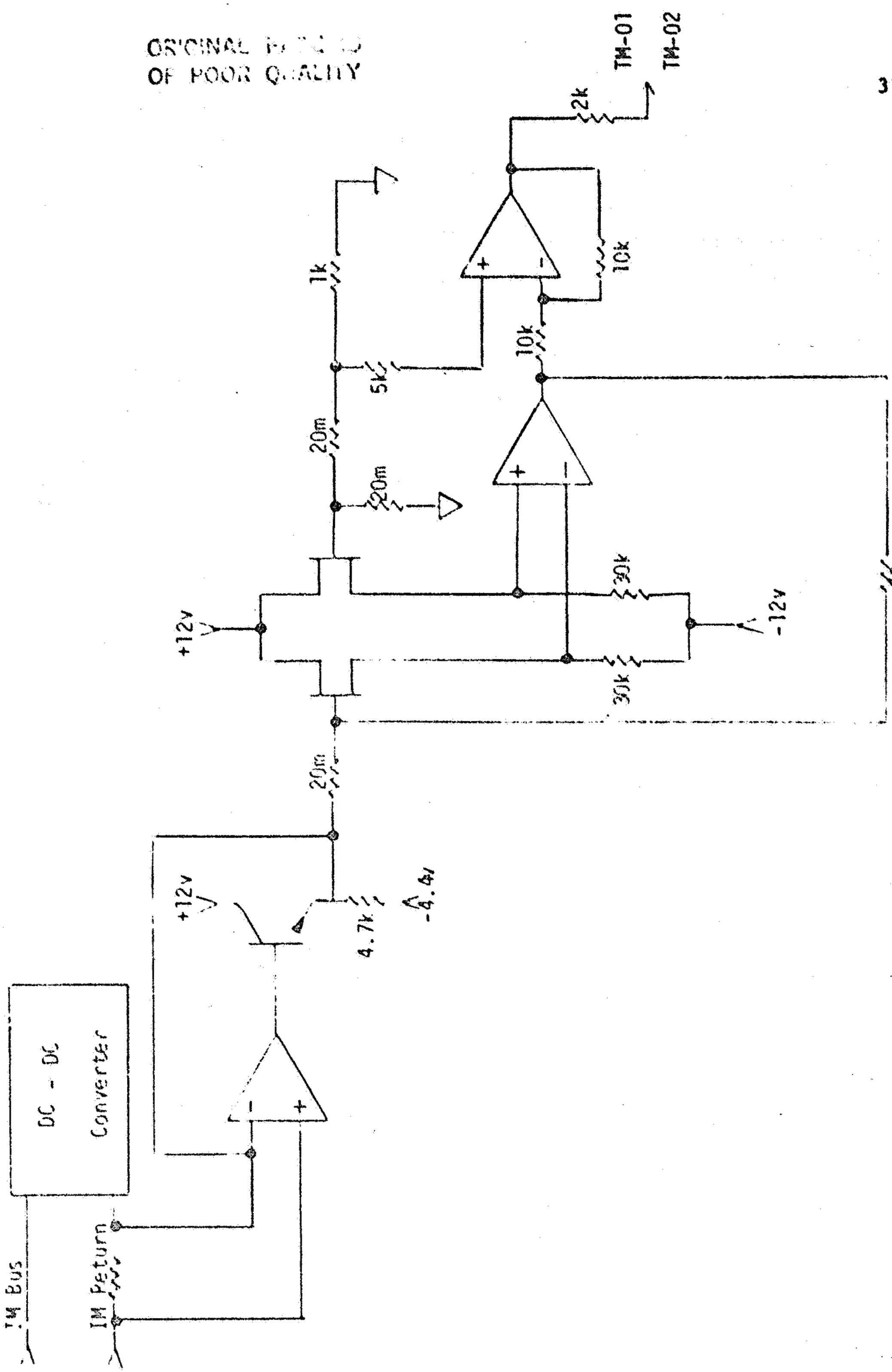


Figure 14.7-1. Power Supply #1 and #2 Input Current

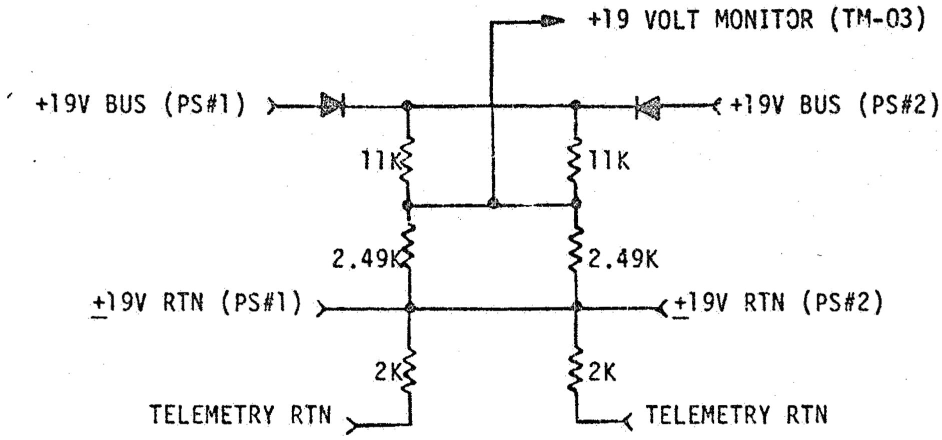


Figure 14.7-2. +19V High Current Bus Monitor

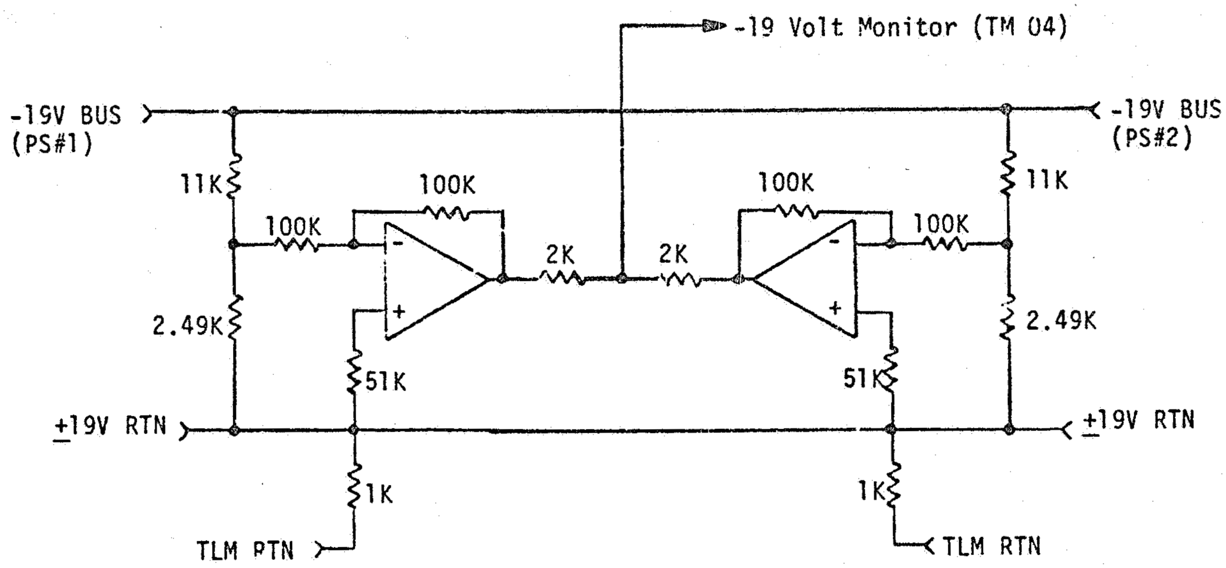


Figure 14.7-3. -19V High Current Bus Monitor

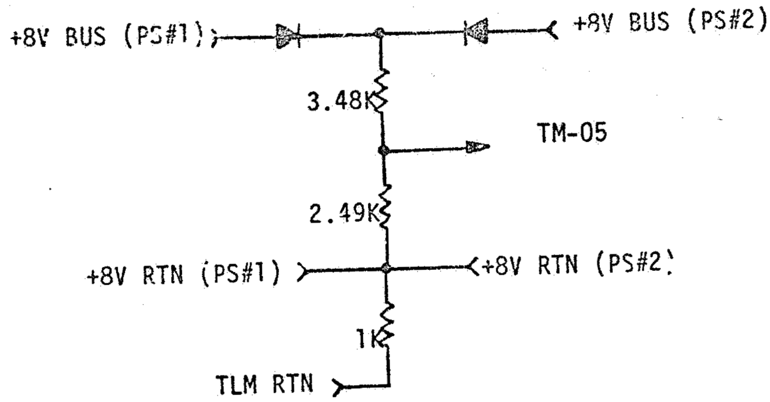


Figure 14.7-4. +8V Bus Monitor

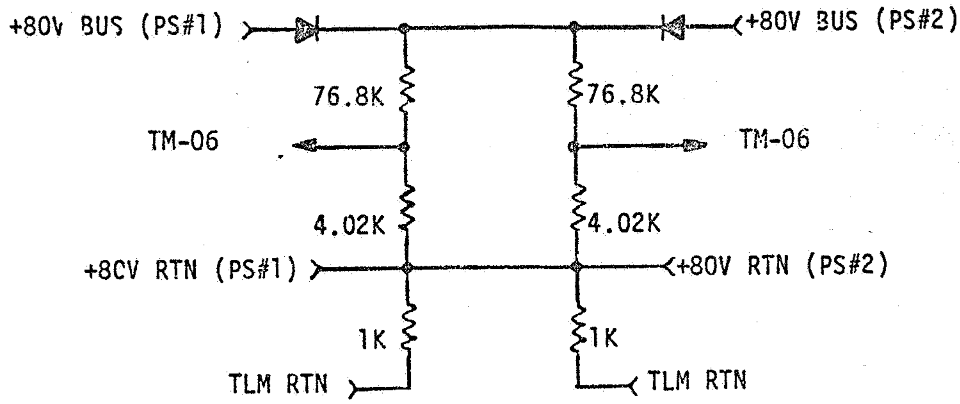


Figure 14.7-5. +80V Bus Monitor

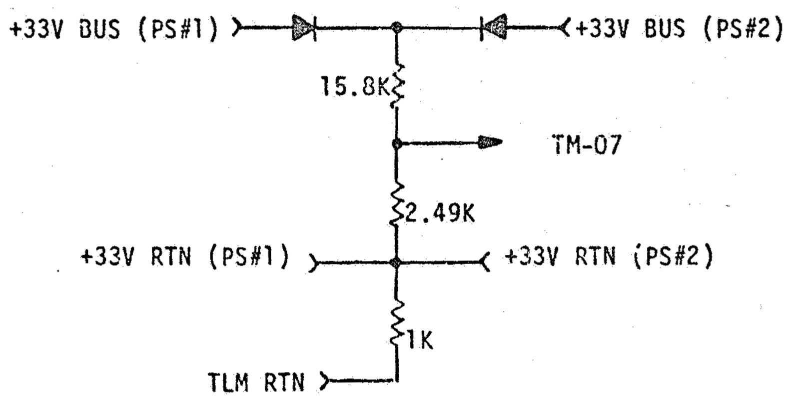


Figure 14.7-6. +33V Bus Monitor

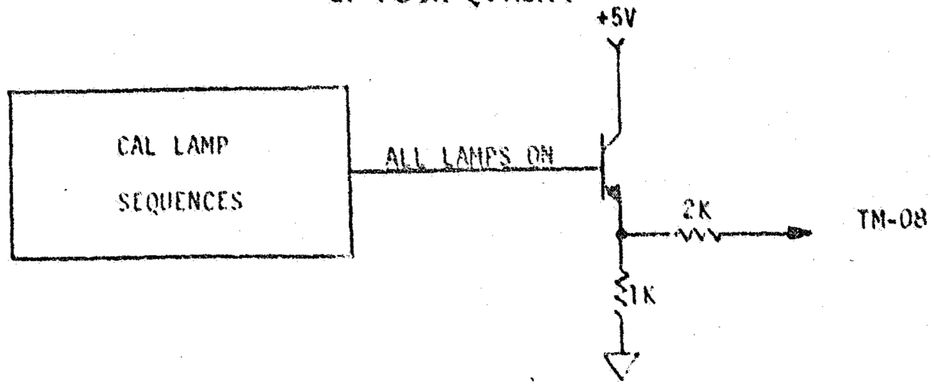
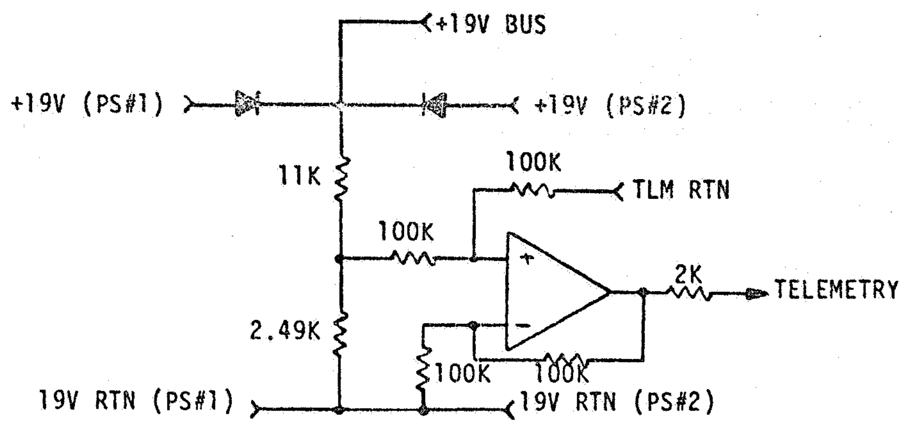
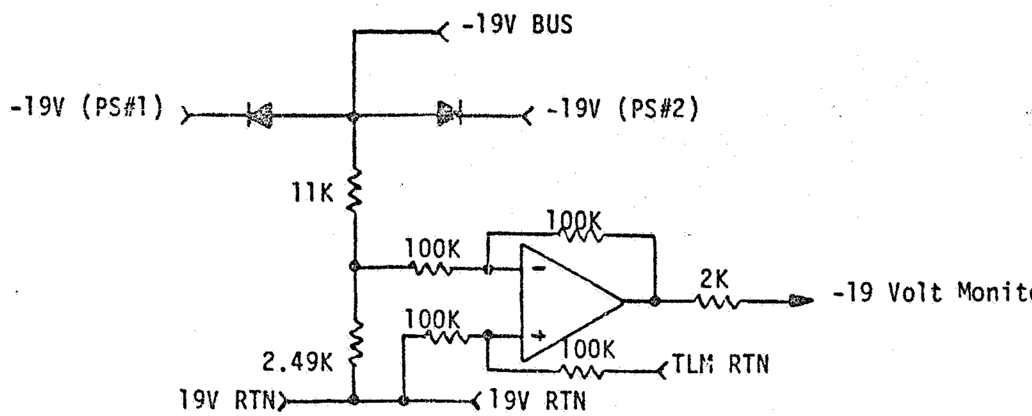


Figure 14.7-7. All Cal Lamps On Monitor



BAND #	ID
1	TM-09
2	TM-11
3	TM-13
4	TM-15
5/7	TM-17
6	TM-19
ISO	TM-21

Figure 14.7-8. Band 1 thru 6 +19V Monitor



BAND #	ID
1	TM-10
2	TM-12
3	TM-14
4	TM-16
5/7	TM-18
6	TM-20
ISO	TM-22

Figure 14.7-9. Band 1 thru 6 -19V Monitor

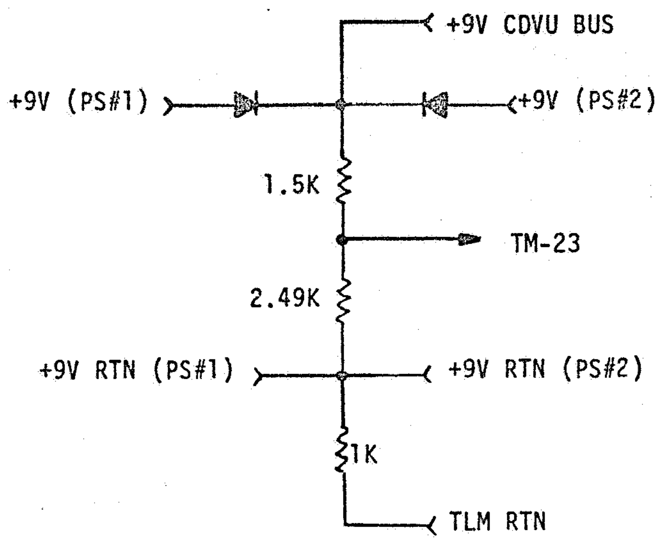


Figure 14.7-10. +9V CDVU Monitor

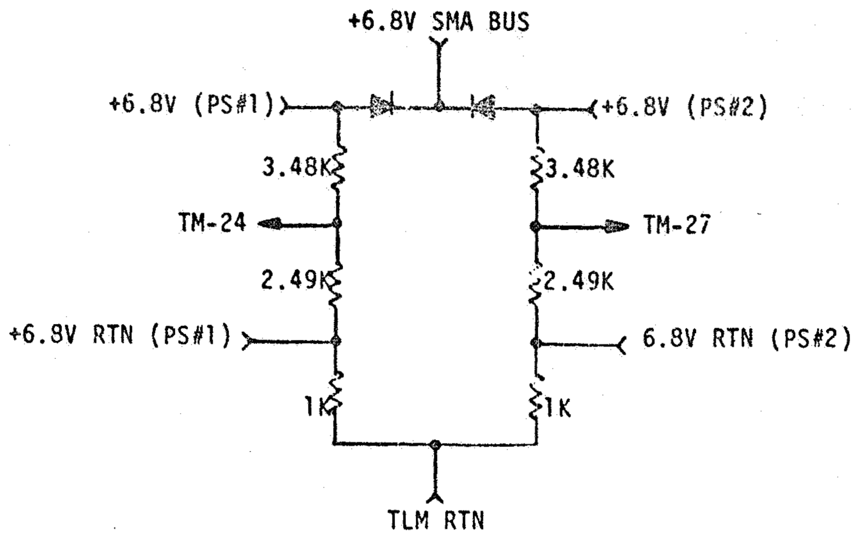


Figure 14.7-11. SMA +6.8V Monitors

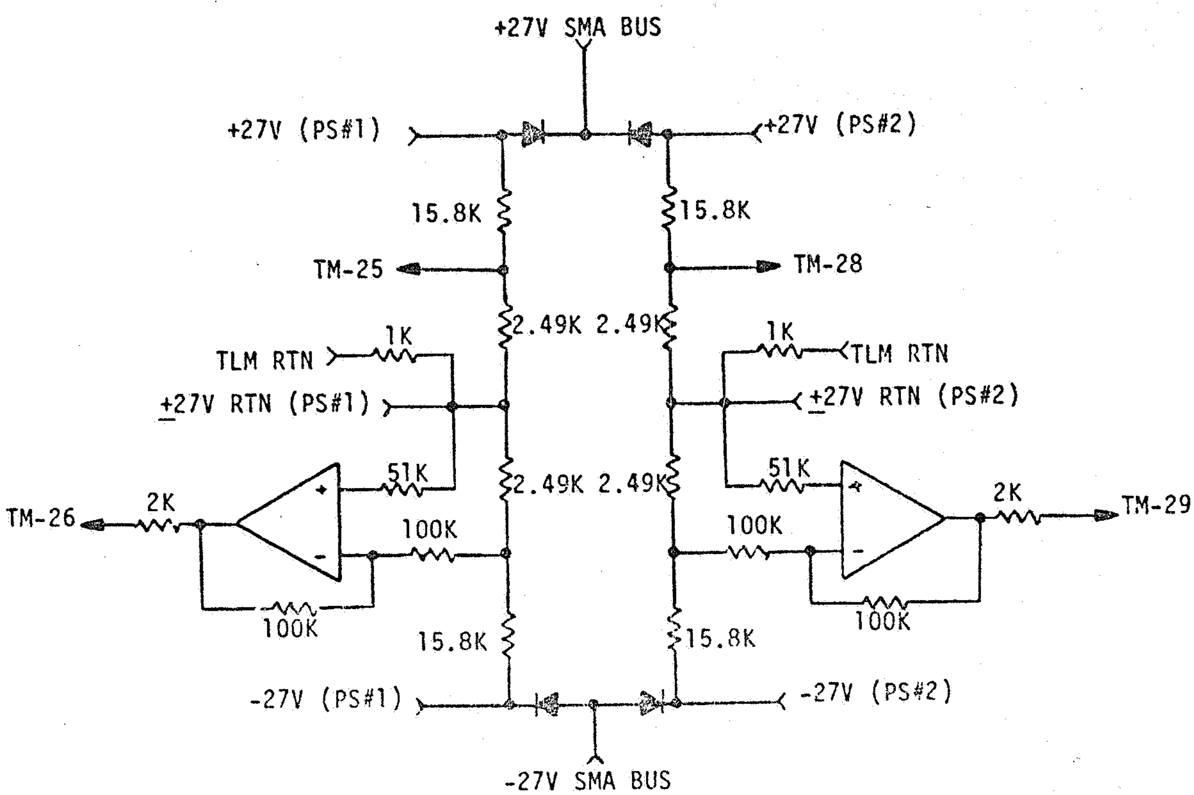


Figure 14.7-12. SMA ±27V Monitors

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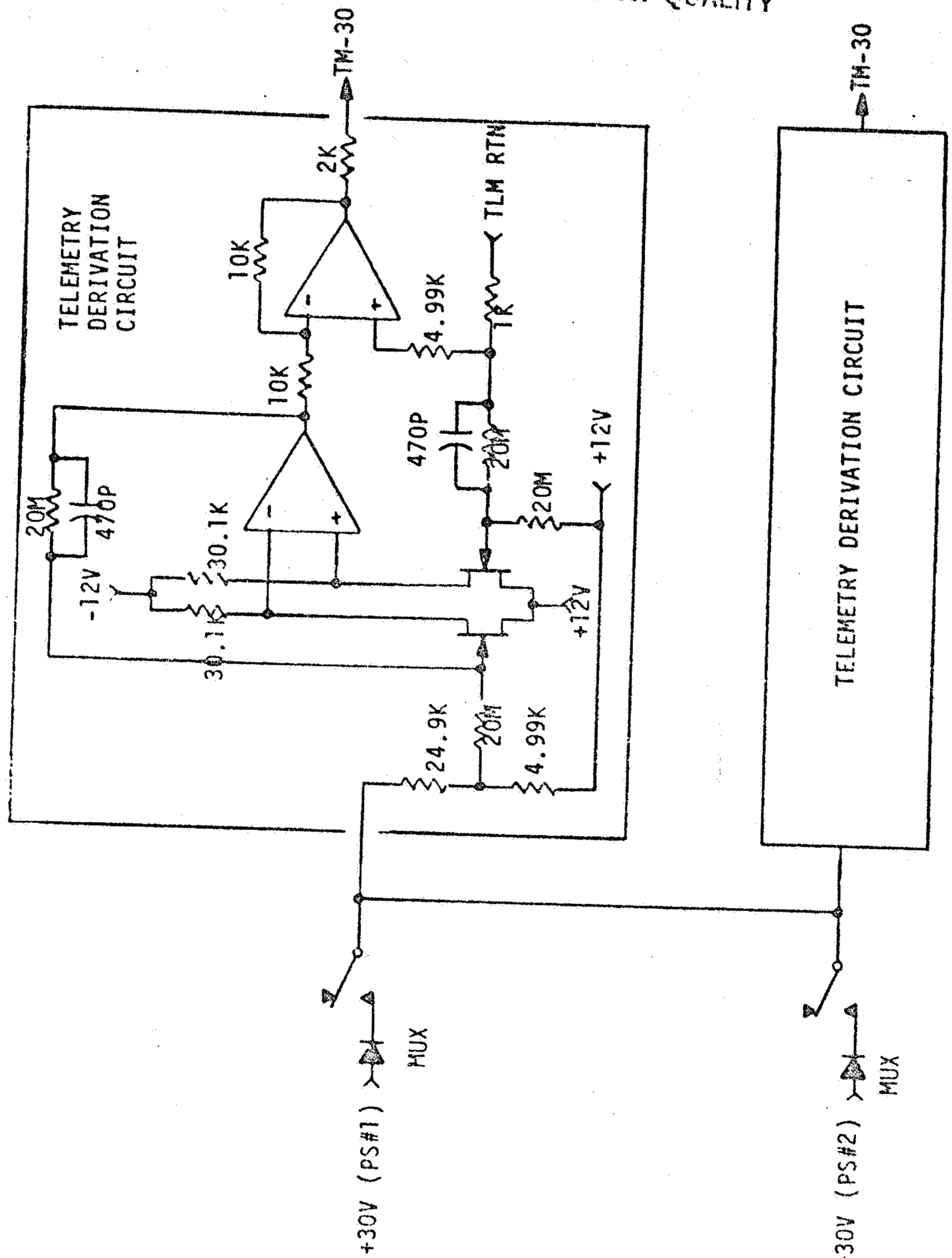


Figure 14.7-13. MUX +30V Monitor

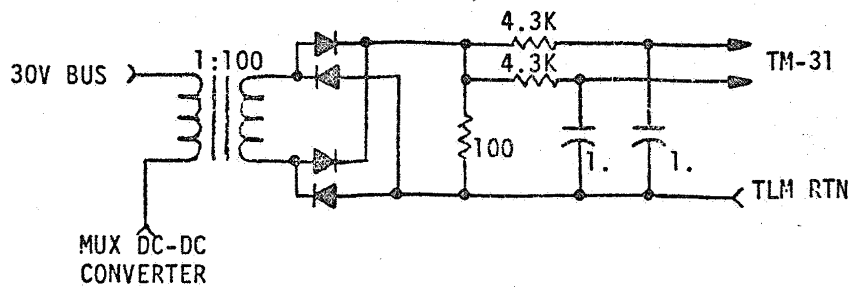


Figure 14.7-14. MUX Input Current Monitor

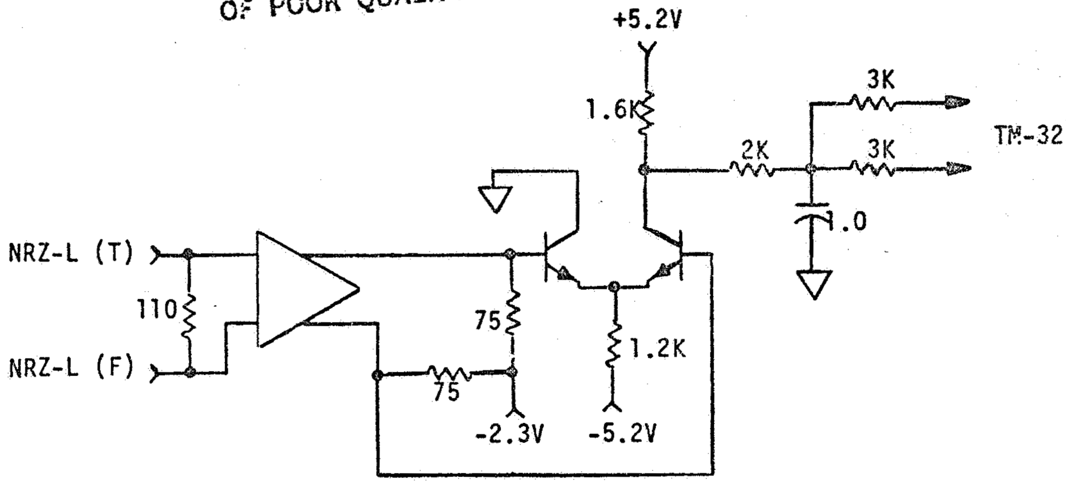


Figure 14.7-15. Multiplexer Bit Density Monitor

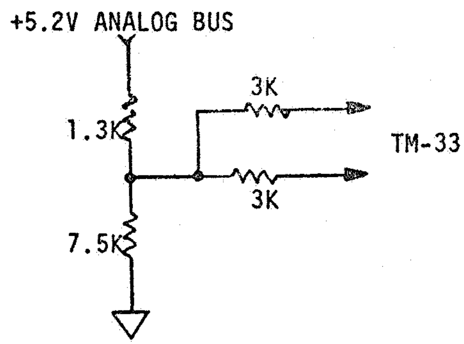


Figure 14.7-16. Multiplexer +5V Monitor

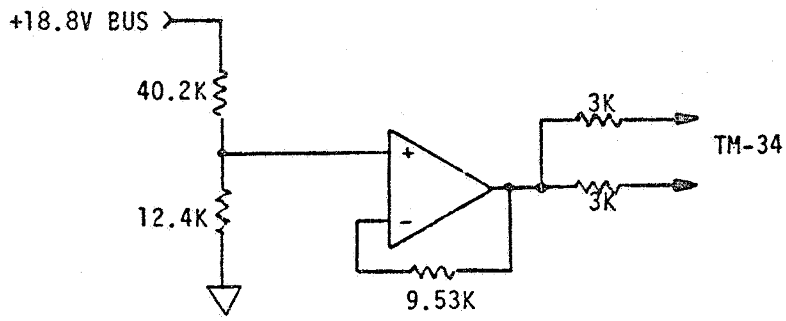


Figure 14.7-17. Multiplexer +18V Monitor

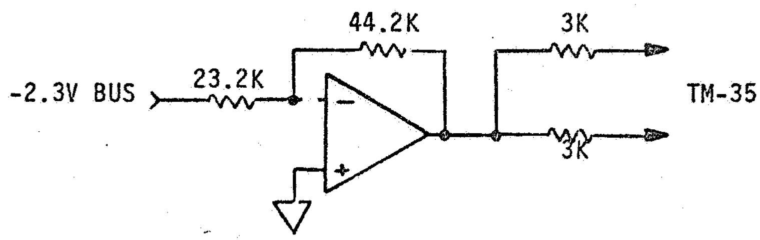


Figure 14.7-18. Multiplexer -3V Monitor

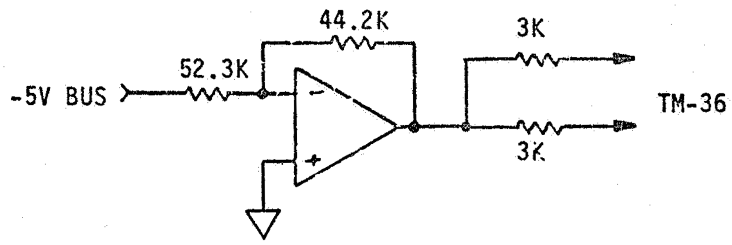


Figure 14.7-19. Multiplexer -5V Monitor

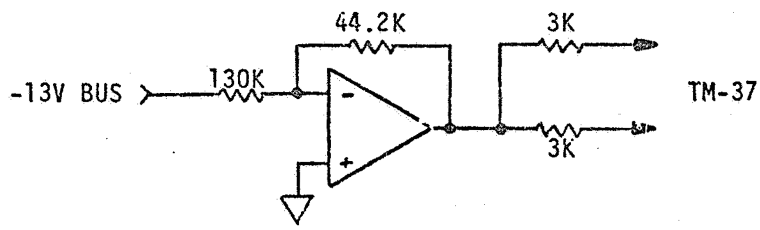
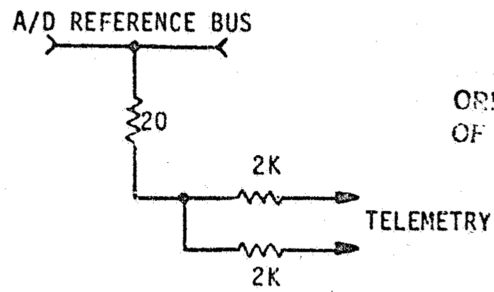


Figure 14.7-20. Multipl er -13V Monitor



NAME	ID
BAND 1 A/D REF	TM-38
2	TM-39
4	TM-40
5	TM-41
6	TM-42
BAND 7 A/D REF	TM-43

Figure 14.7-21. A/D Reference Voltage Monitor

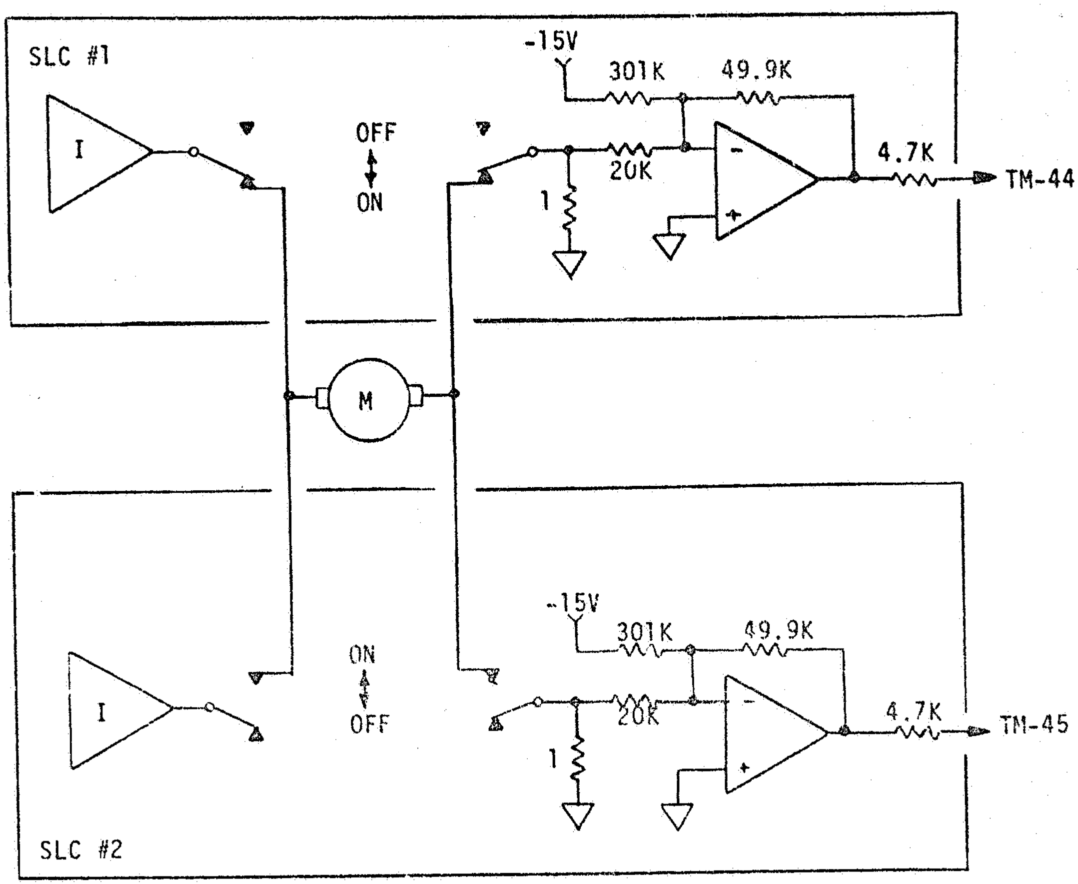


Figure 14.7-22. Scan Line Corrector Drive Current Monitor

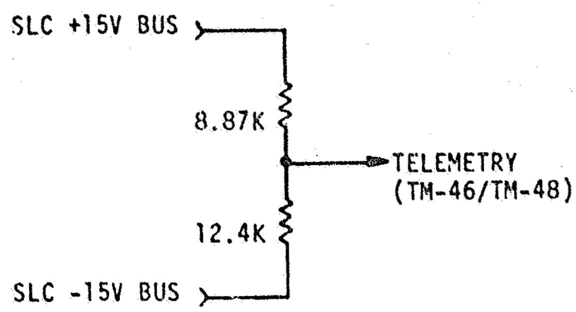


Figure 14.7-23. SLC ±15V Monitor

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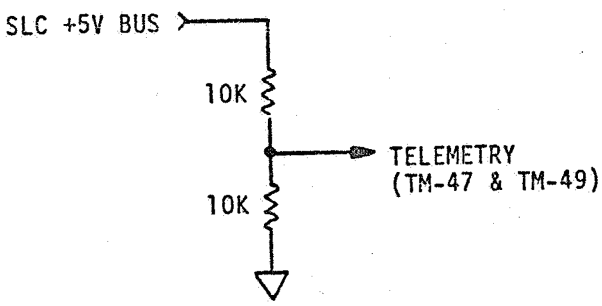
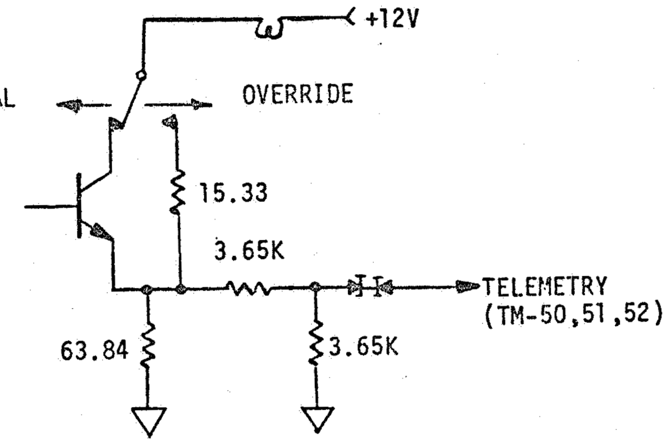


Figure 14.7-24. SLC +5V Monitor



LAMP #	ID
1	TM-50
2	TM-51
3	TM-52

Figure 14.7-25. Calibration Lamp Current Monitor

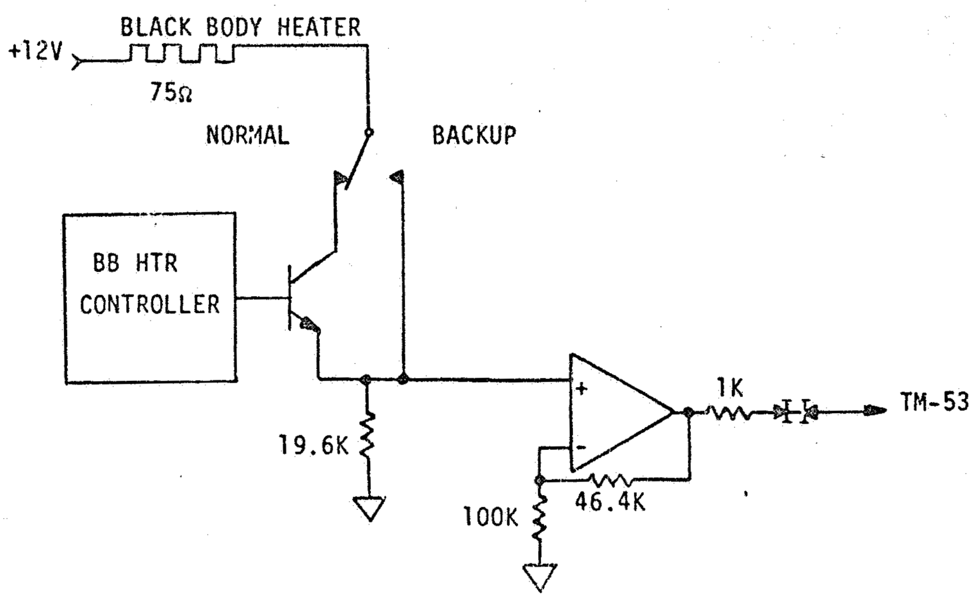


Figure 14.7-26. Blackbody Heater Current Monitor

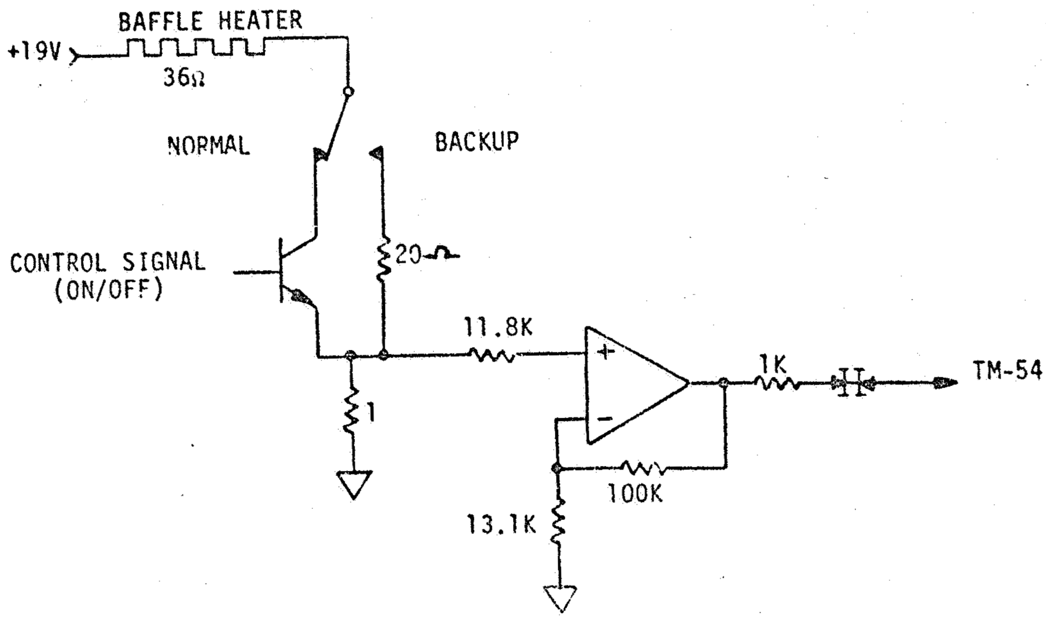


Figure 14.7-27. Baffle Heater Current Monitor

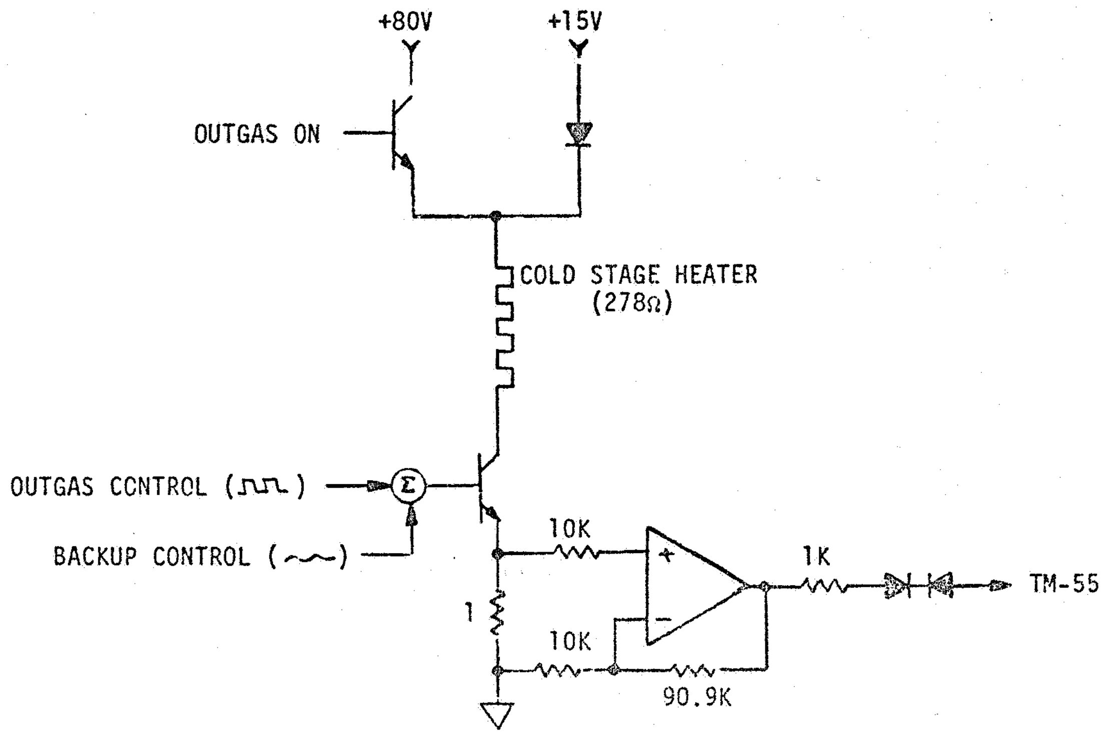


Figure 14.7-28. Cold Stage Heater Current Monitor

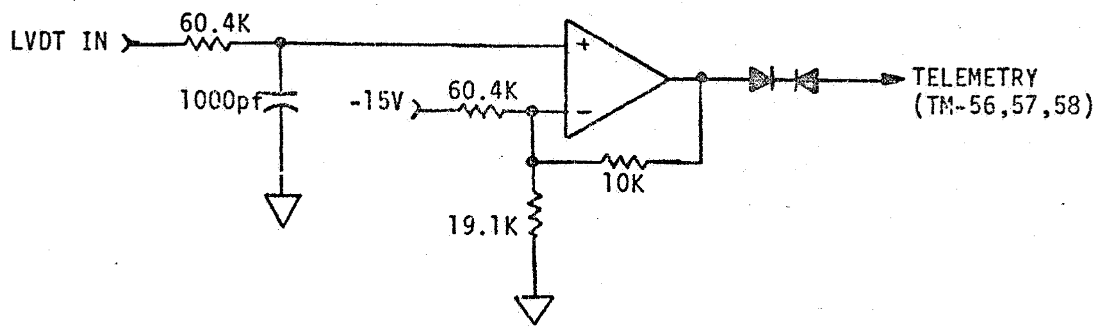


Figure 14.7-29. Inchworm Position Monitor

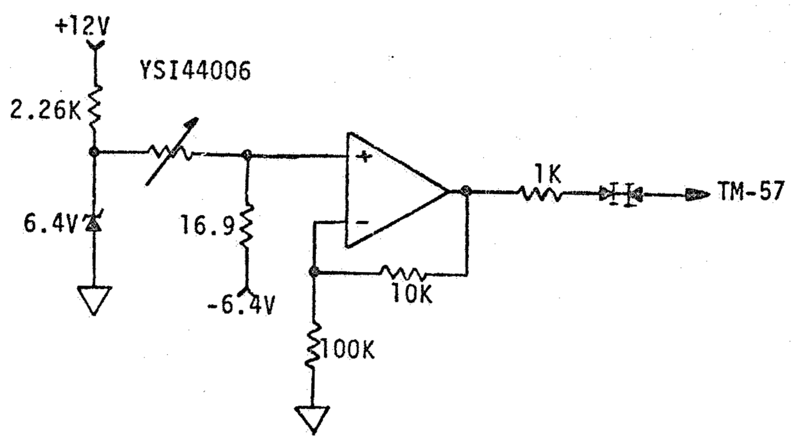


Figure 14.7-30. Blackbody Temperature Monitor

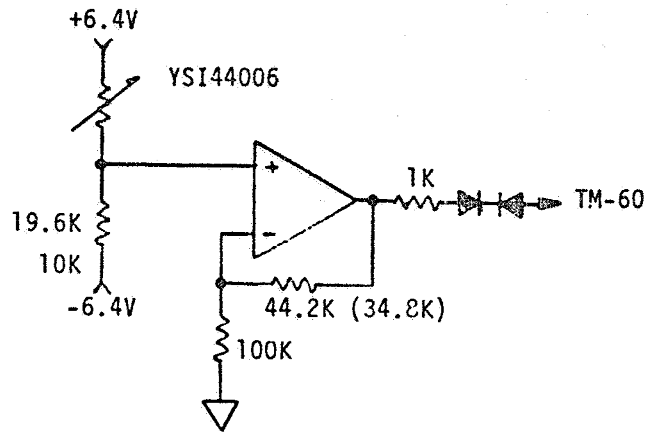


Figure 14.7-31. SIFP Temperature Monitor

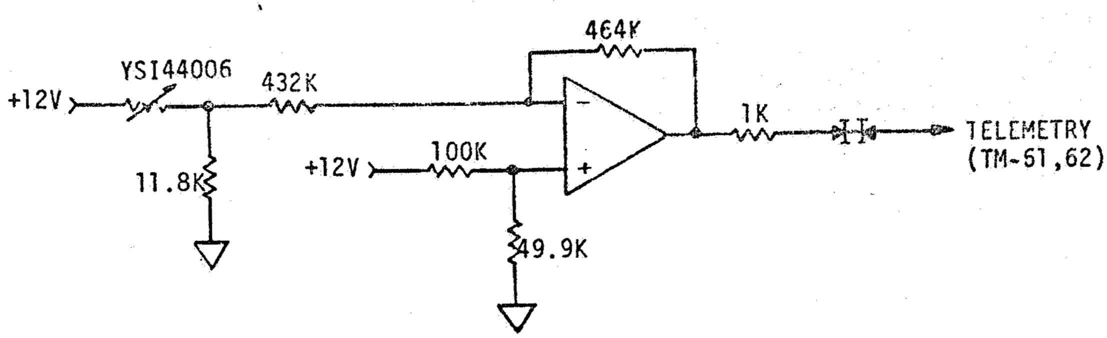


Figure 14.7-32. Shutter Temperature Monitor

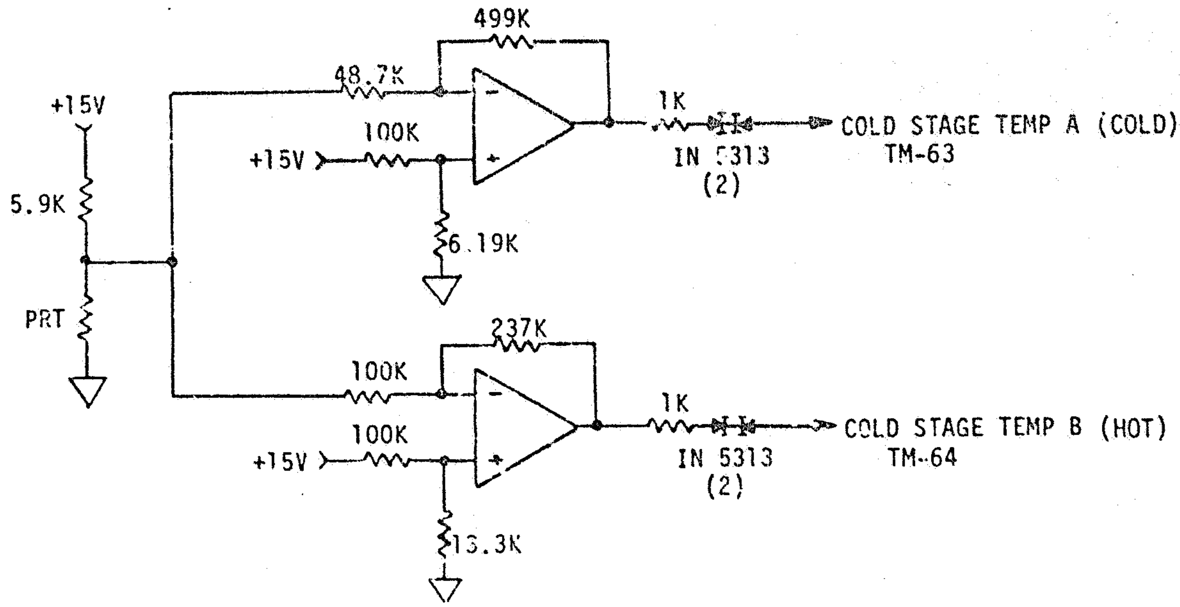


Figure 14.7-33. Cold Stage Temperature Monitors

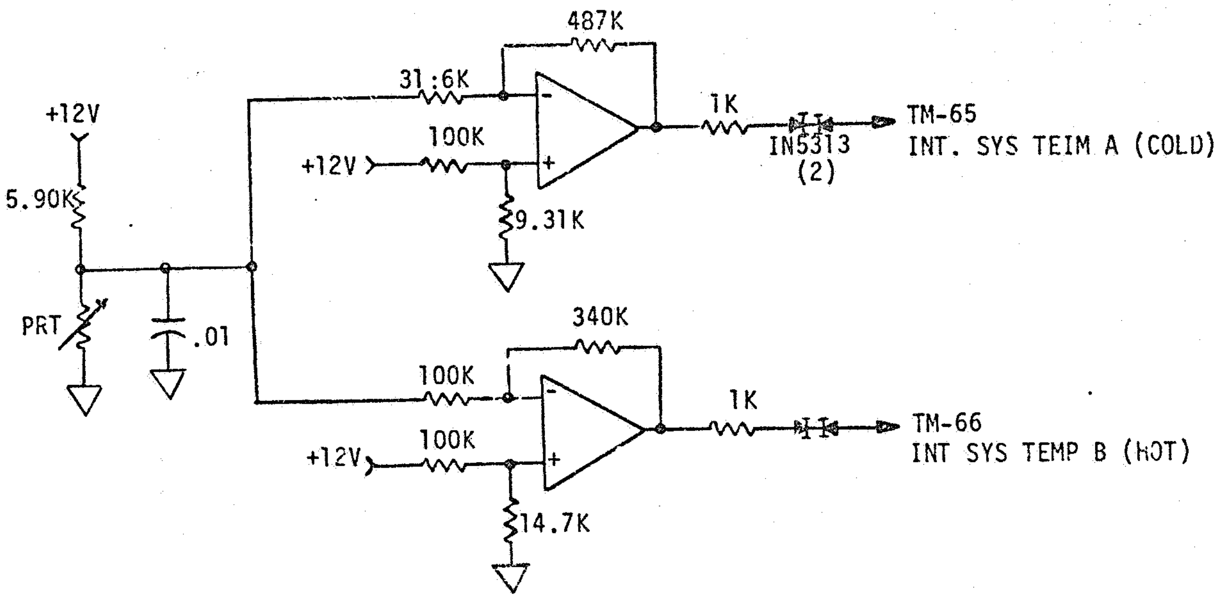


Figure 14.7-34. Intermediate Stage Temperature Monitors

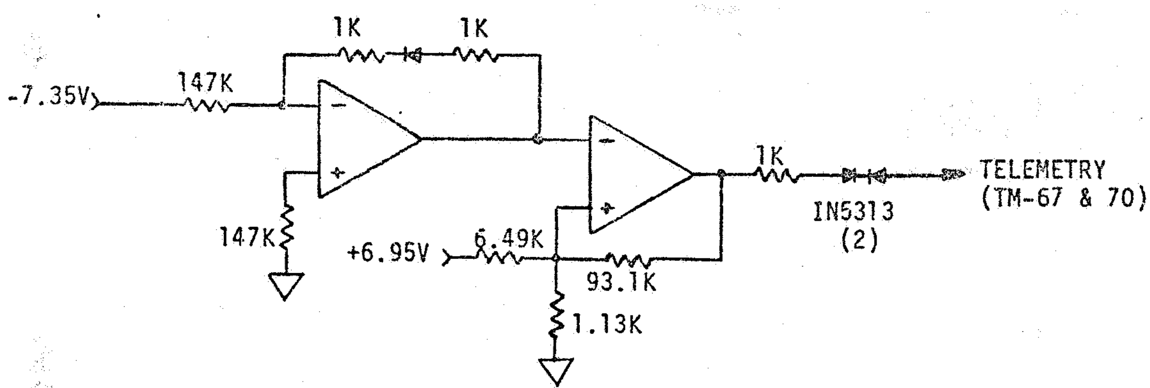


Figure 14.7-35. CFPA Temperature Monitor

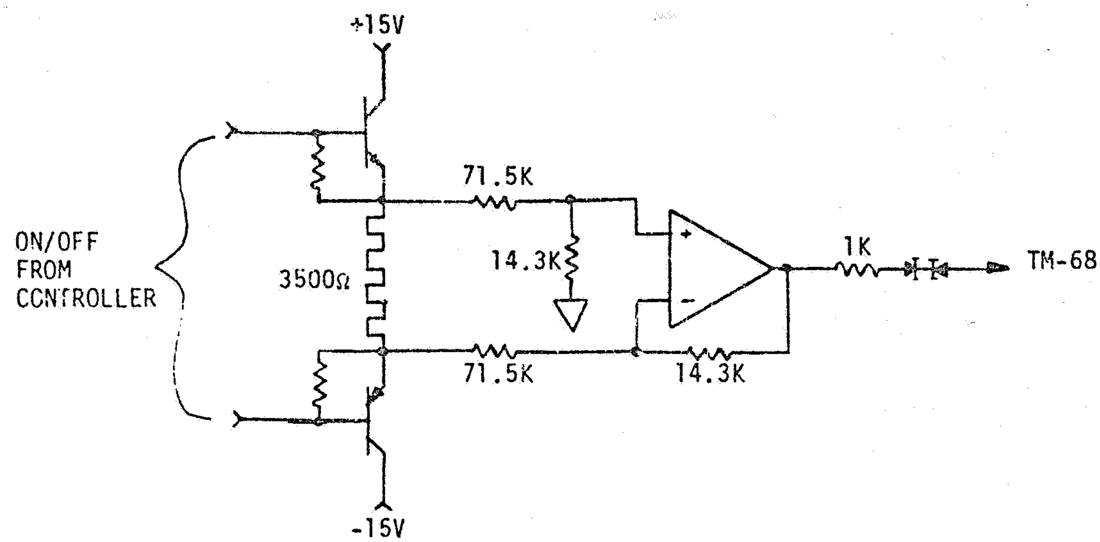


Figure 14.7-36. CFPA Heater Current Monitor

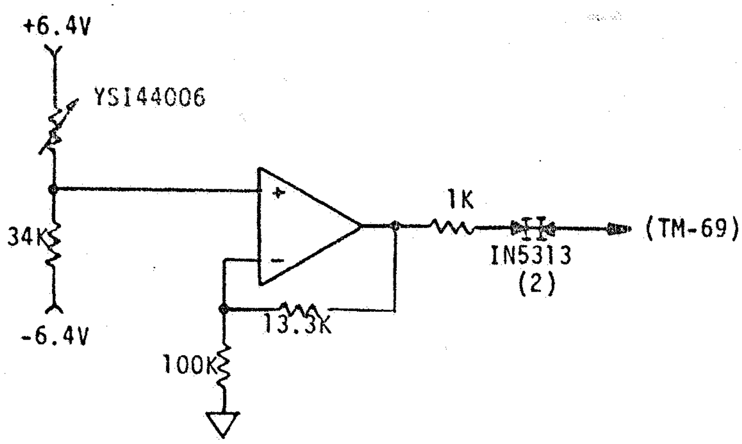
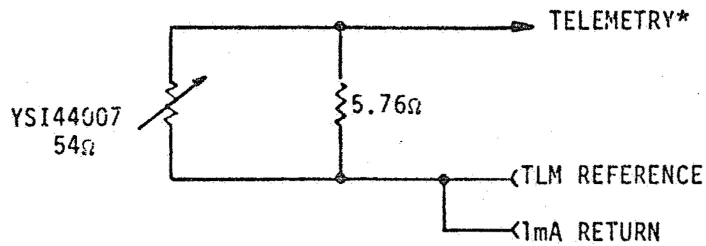


Figure 14.7-37. Baffle Temperature Monitor



TM-71, 72, 73, 74, 75, 79, 80, 81, 82, 84, 85, 86, 93, 94, 95, 96, 97, 100

Figure 14.7-38. Type 1 Temperature Monitor

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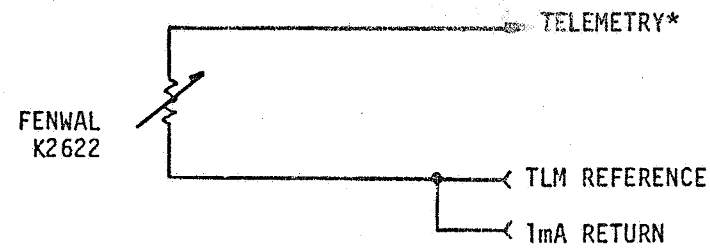
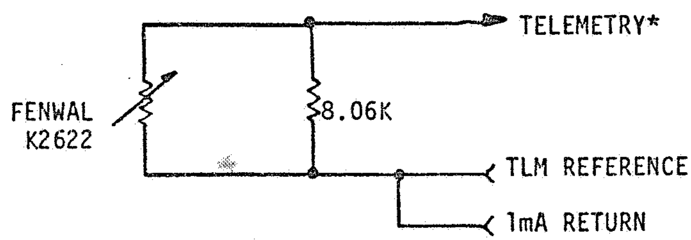


*TM-87, 88, 89, 90, 91, 92

Figure 14.7-39. Tyep 2 Temperature Monitor



*TM-76, 77, 78, 83, 98, 99

Figure 14.7-40. Type 3 Temperature Monitor

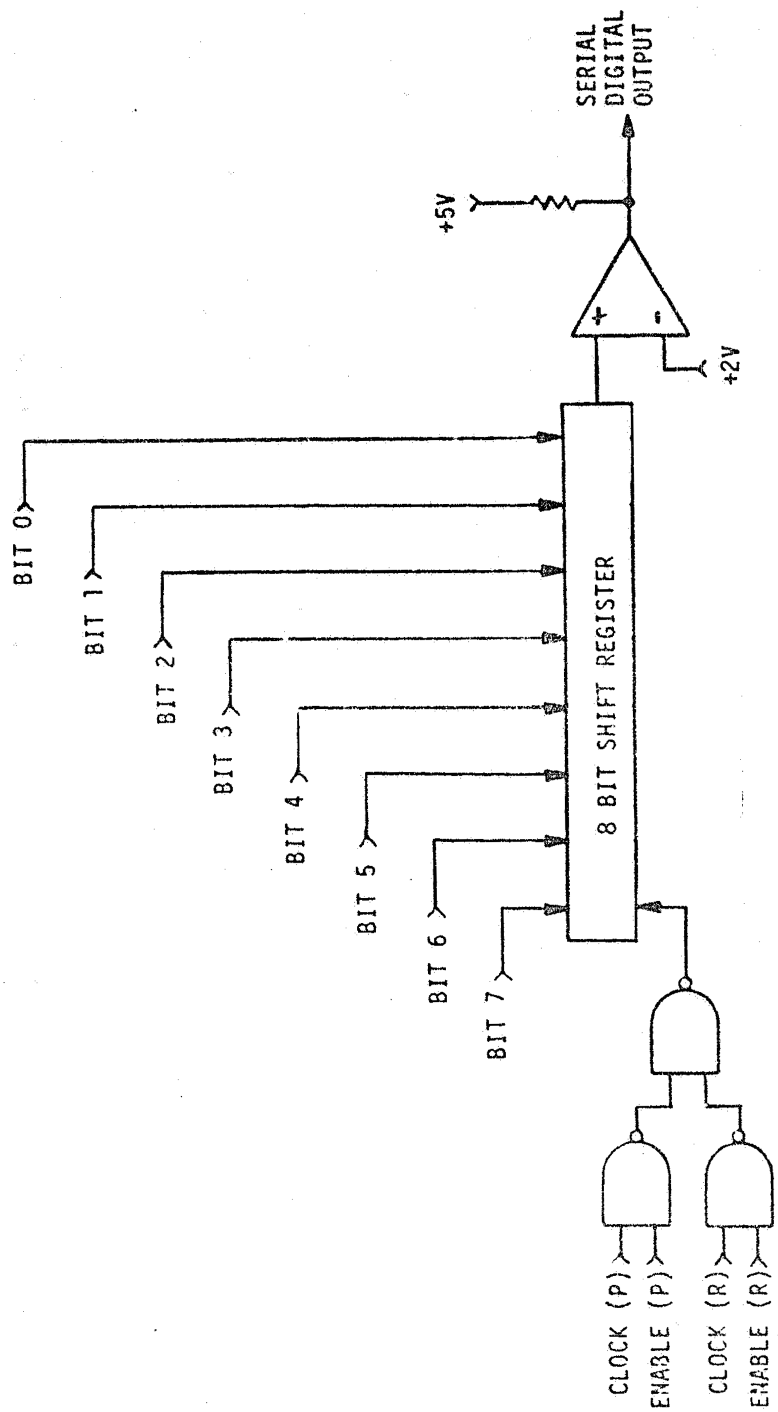


Figure 14.7-41. Serial Digital Telemetry Word Derivation

TBD

(TO BE SUPPLIED BY HUGHES)

Figure 14.7-42. Thermal Shut Down Status Monitor

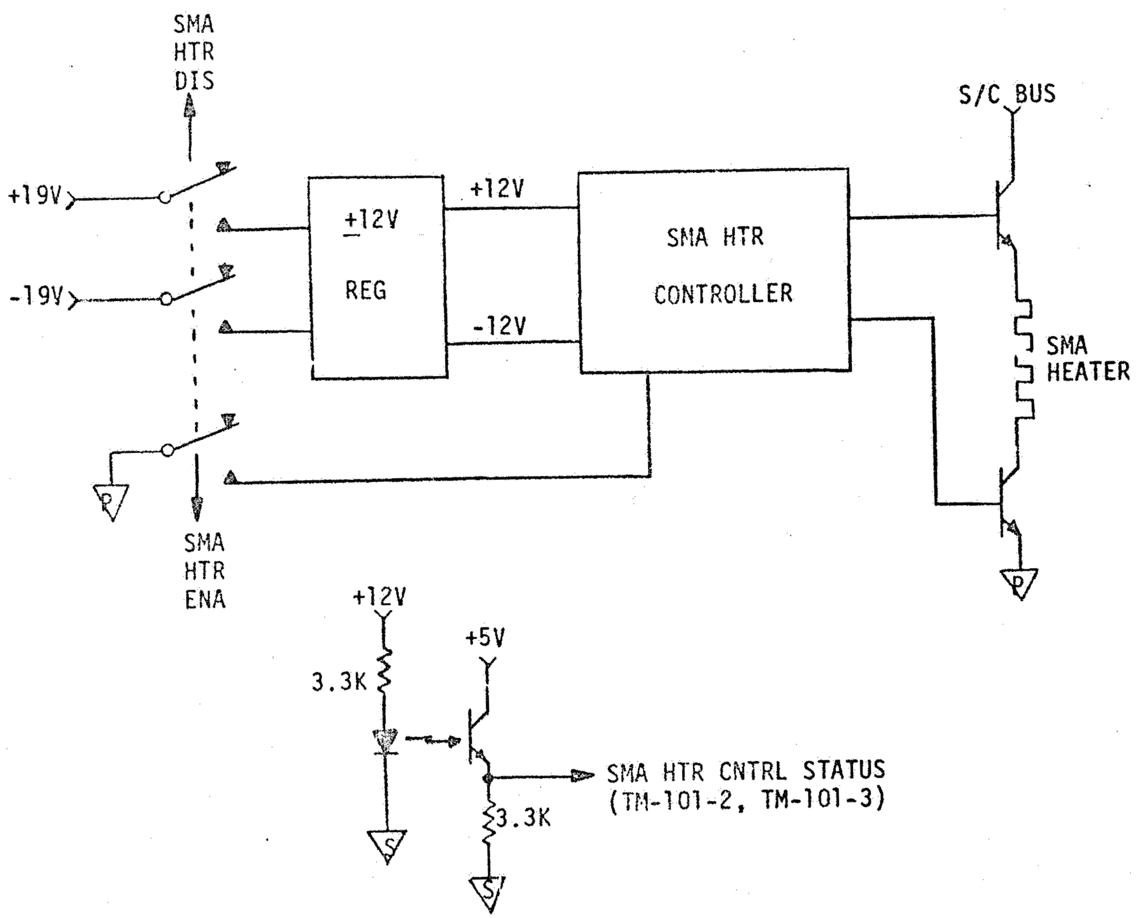


Figure 14.7-43. SMA + or - Z Heater Controller Status Monitor

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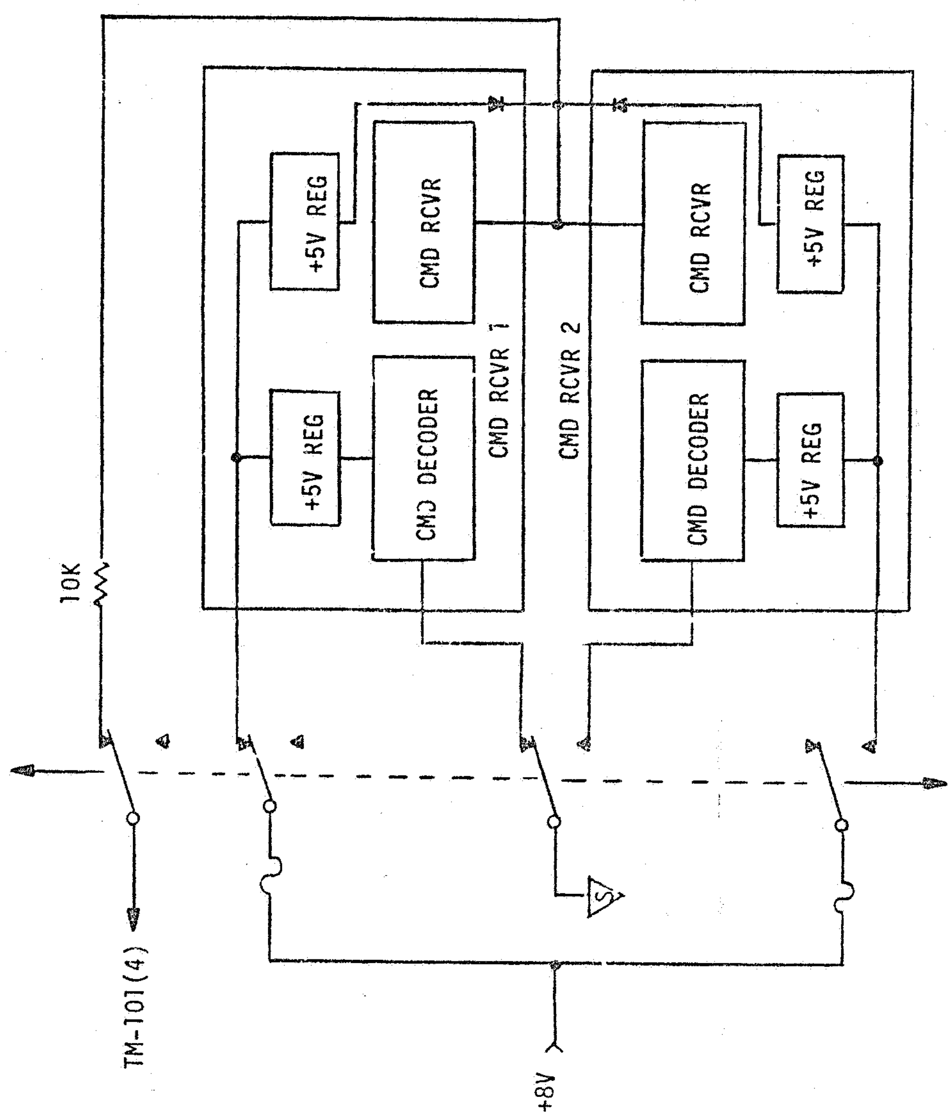

Figure 14.7-44. Serial Command Receiver Status Monitor

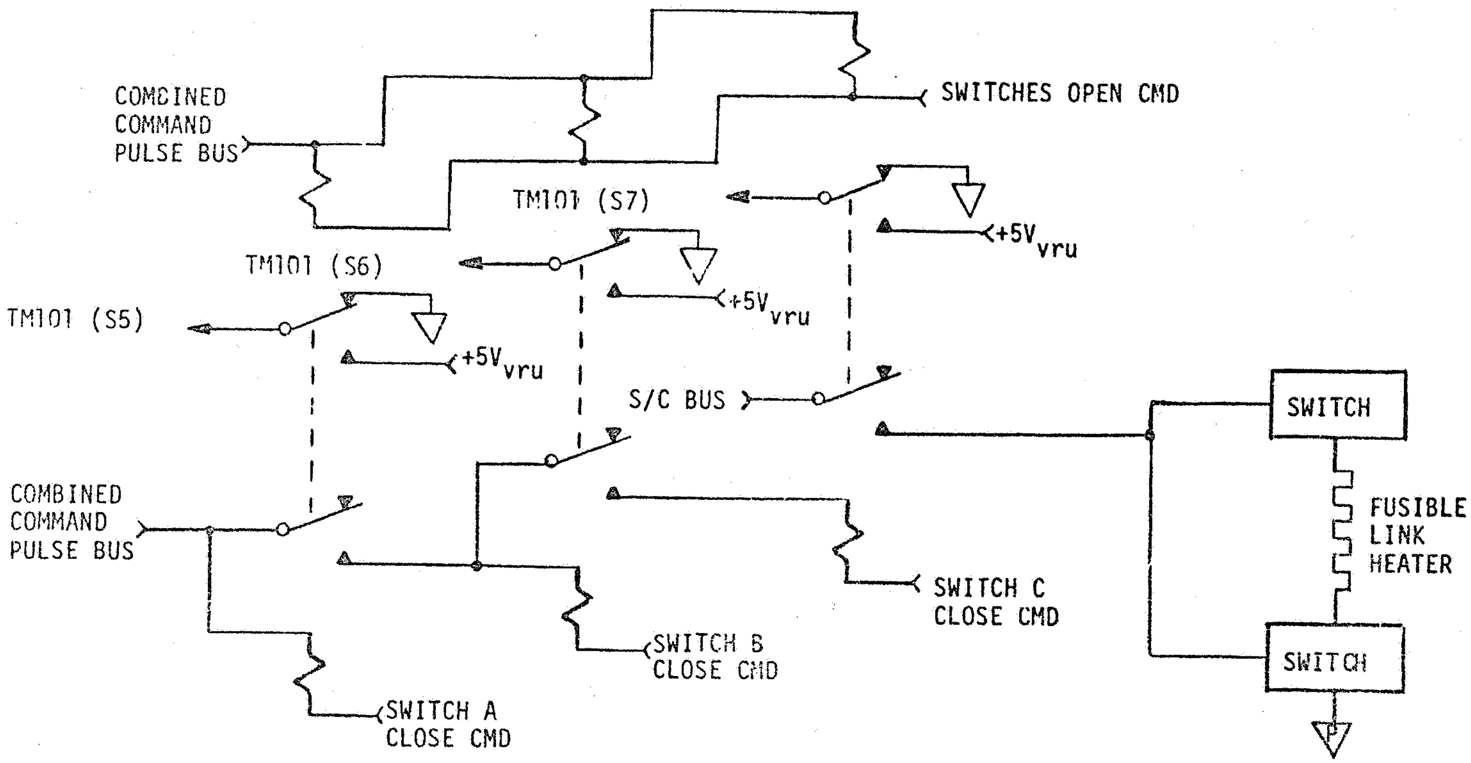

Figure 14.7-45. Fusible Link Switch Status Monitors

BAND #		1	2	3	4	5	6	7
CMD #	ON	718	754	728	758	819	847	815
	OFF	752	724	756	730	845	825	841
TLM B, t, #		S0	S1	S2	S3	S4	S5	S5

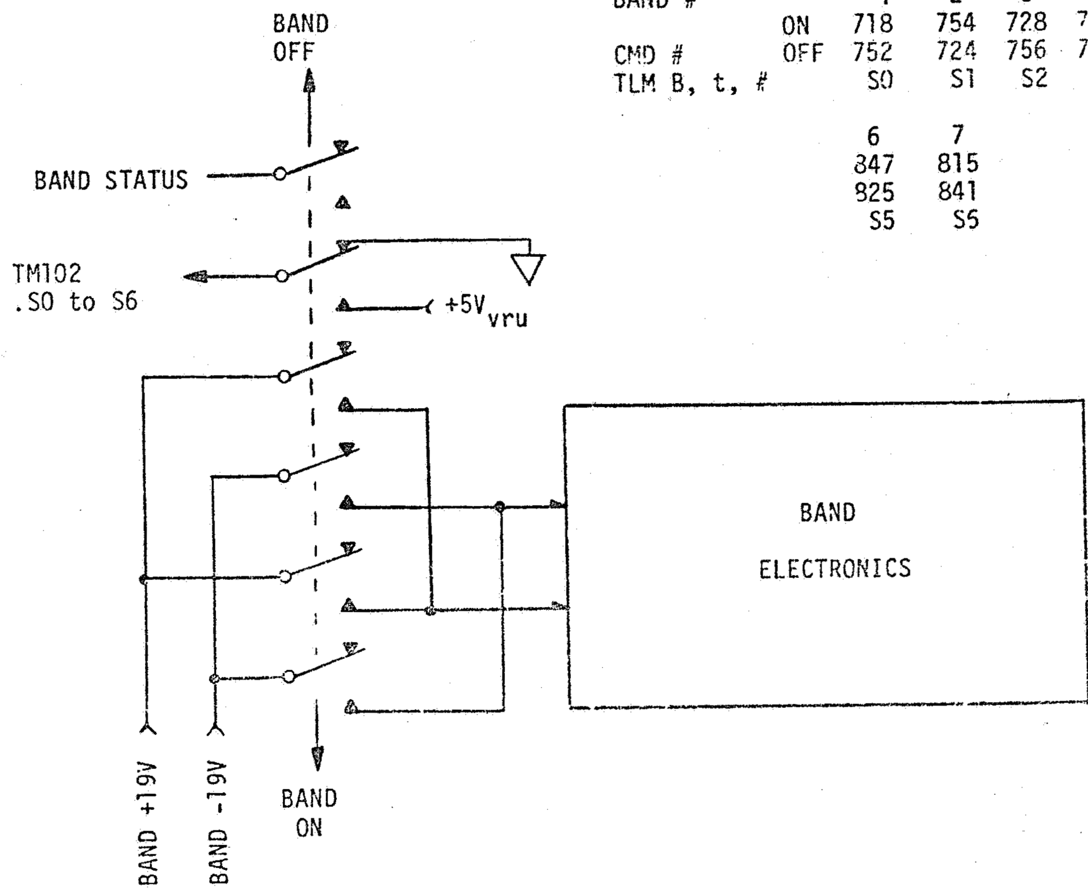

Figure 14.7-46. Band 1 thru 7 Status Monitor

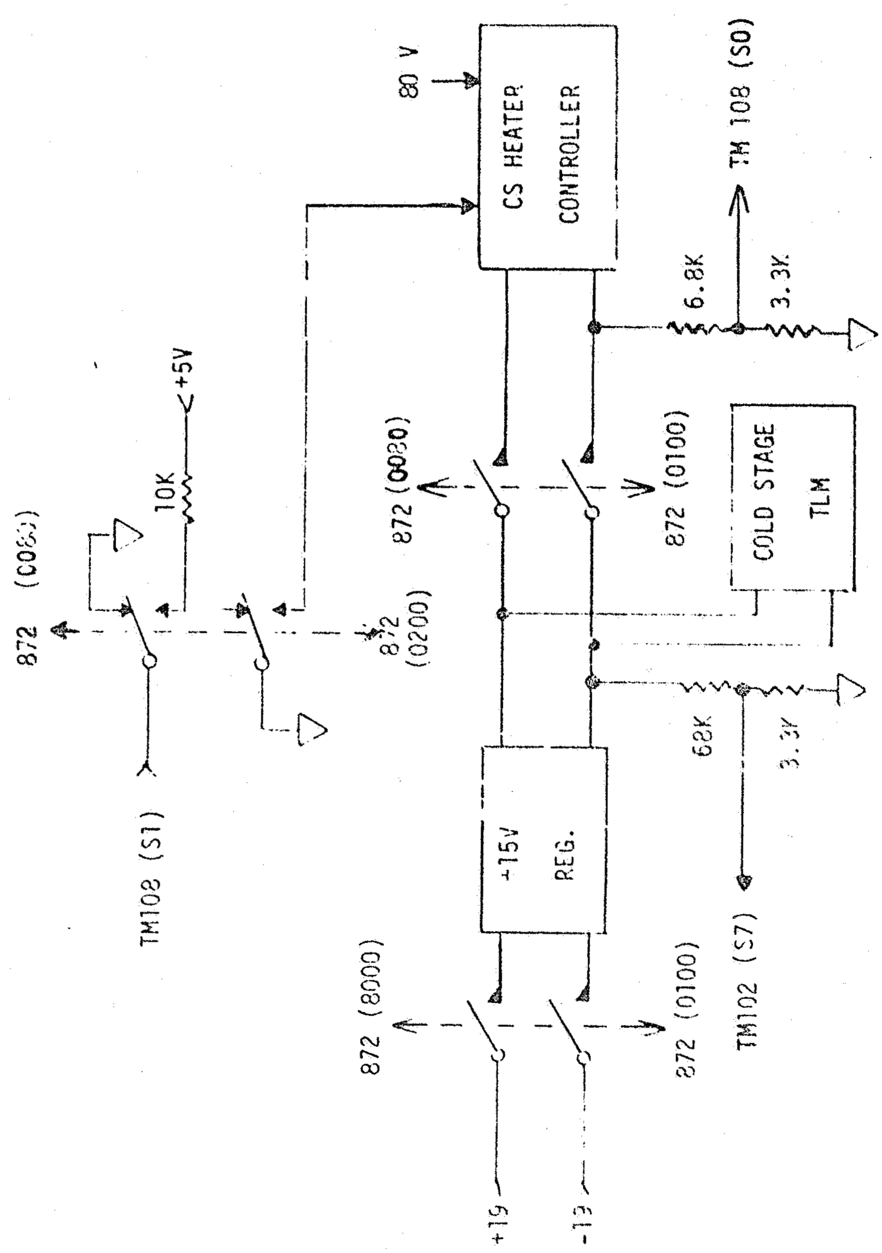

Figure 14.7-47. Cold Stage Heater Controller Status Monitor

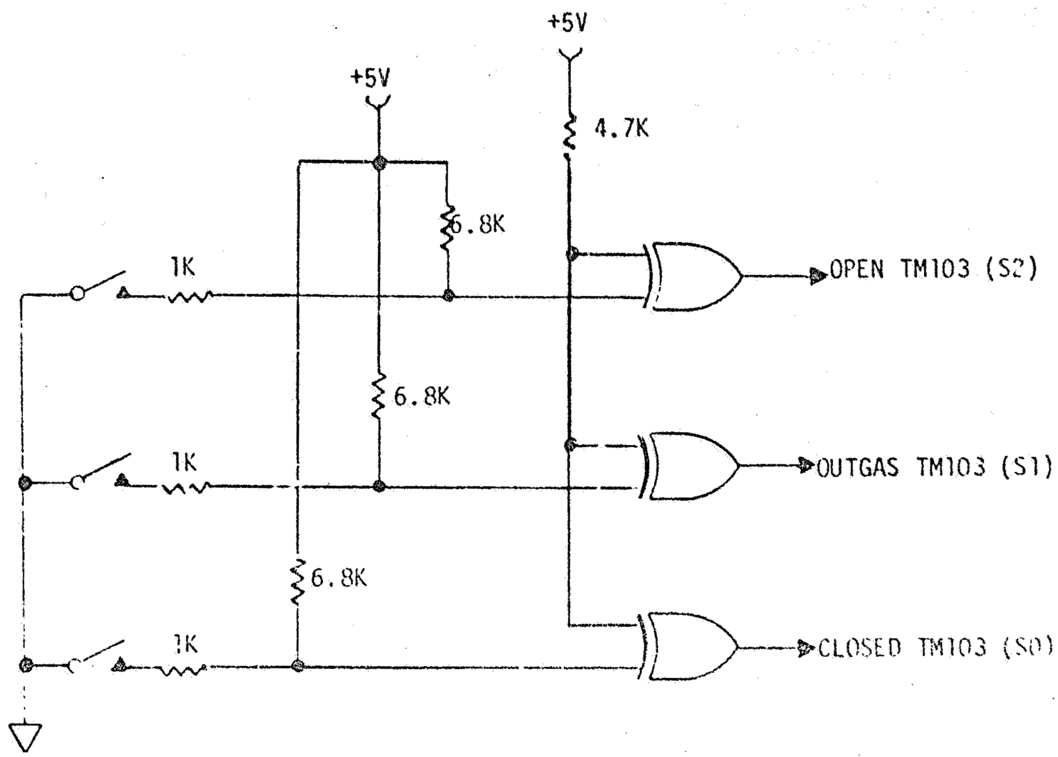

Figure 14.7-48. Door Position Status Monitor

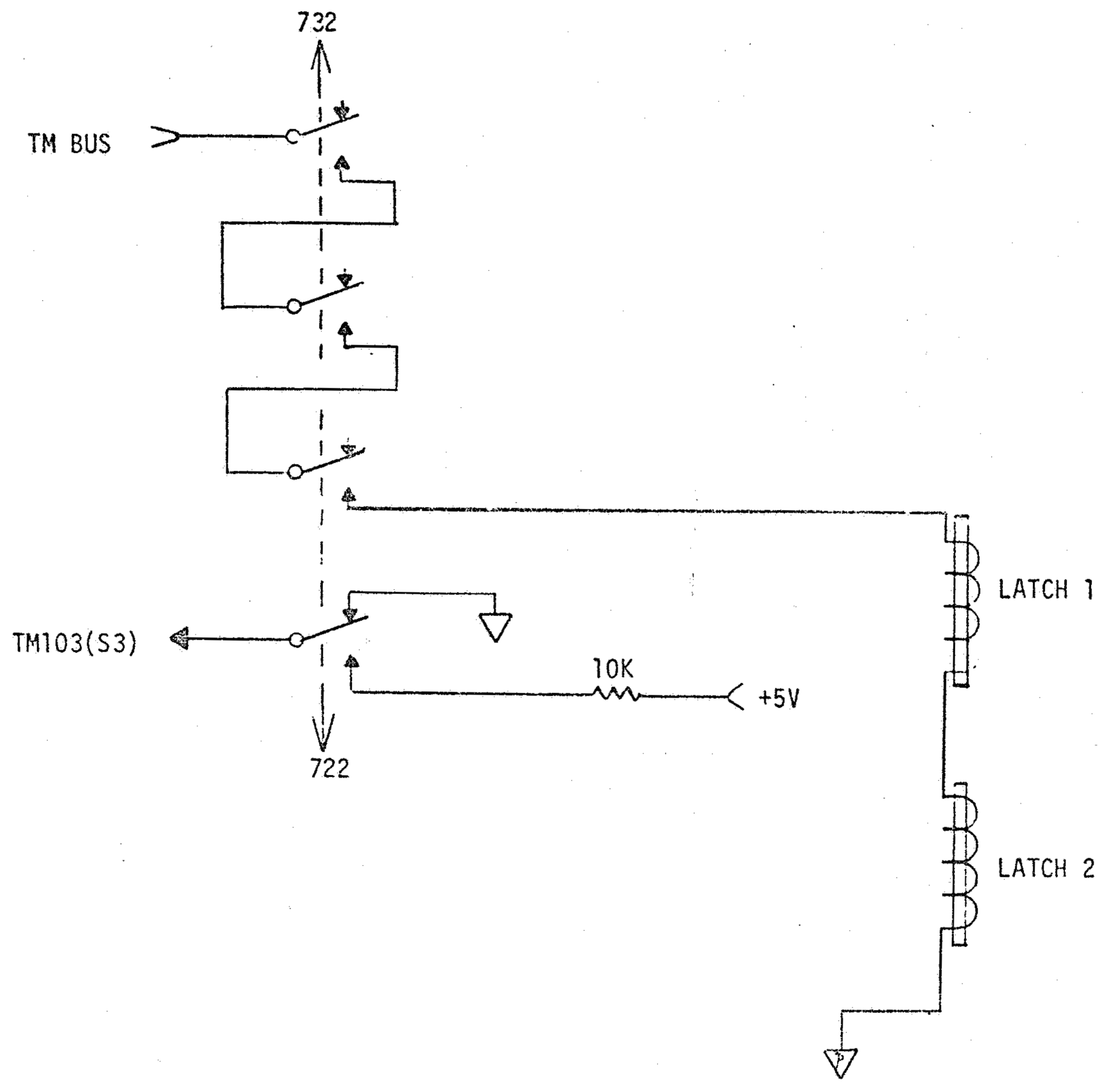

Figure 14.7-49. Door Latch Status Monitor

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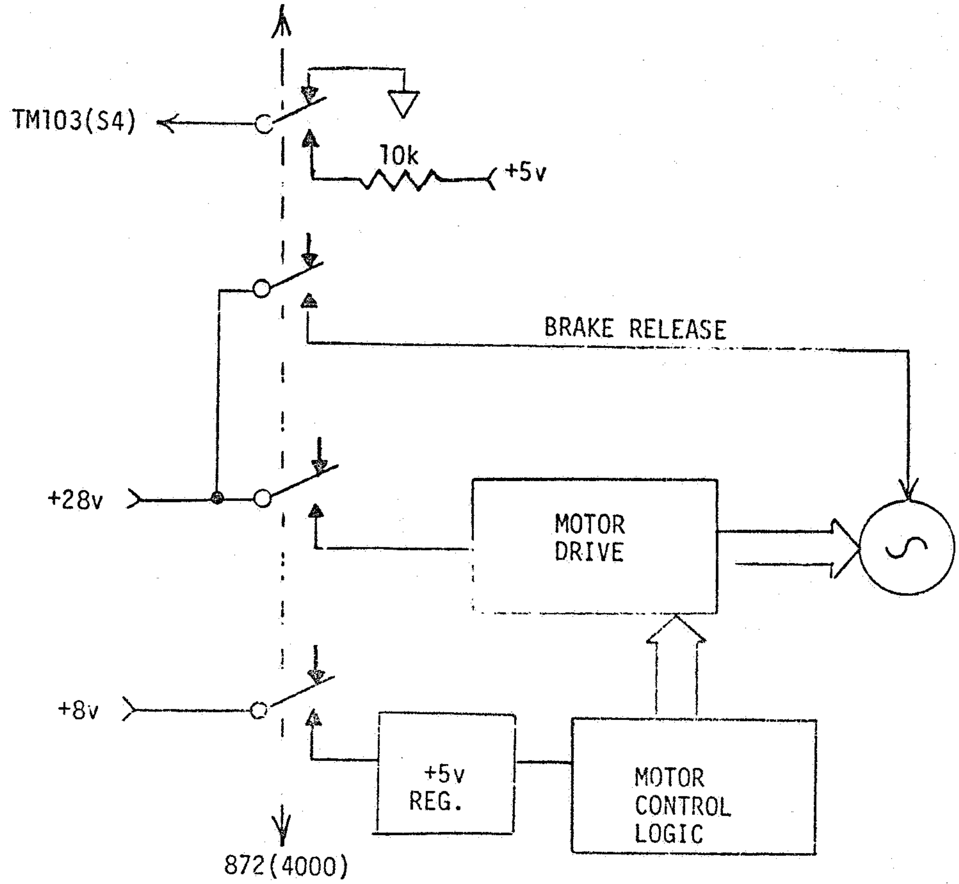

Figure 14.7-50. Motor Control Monitor

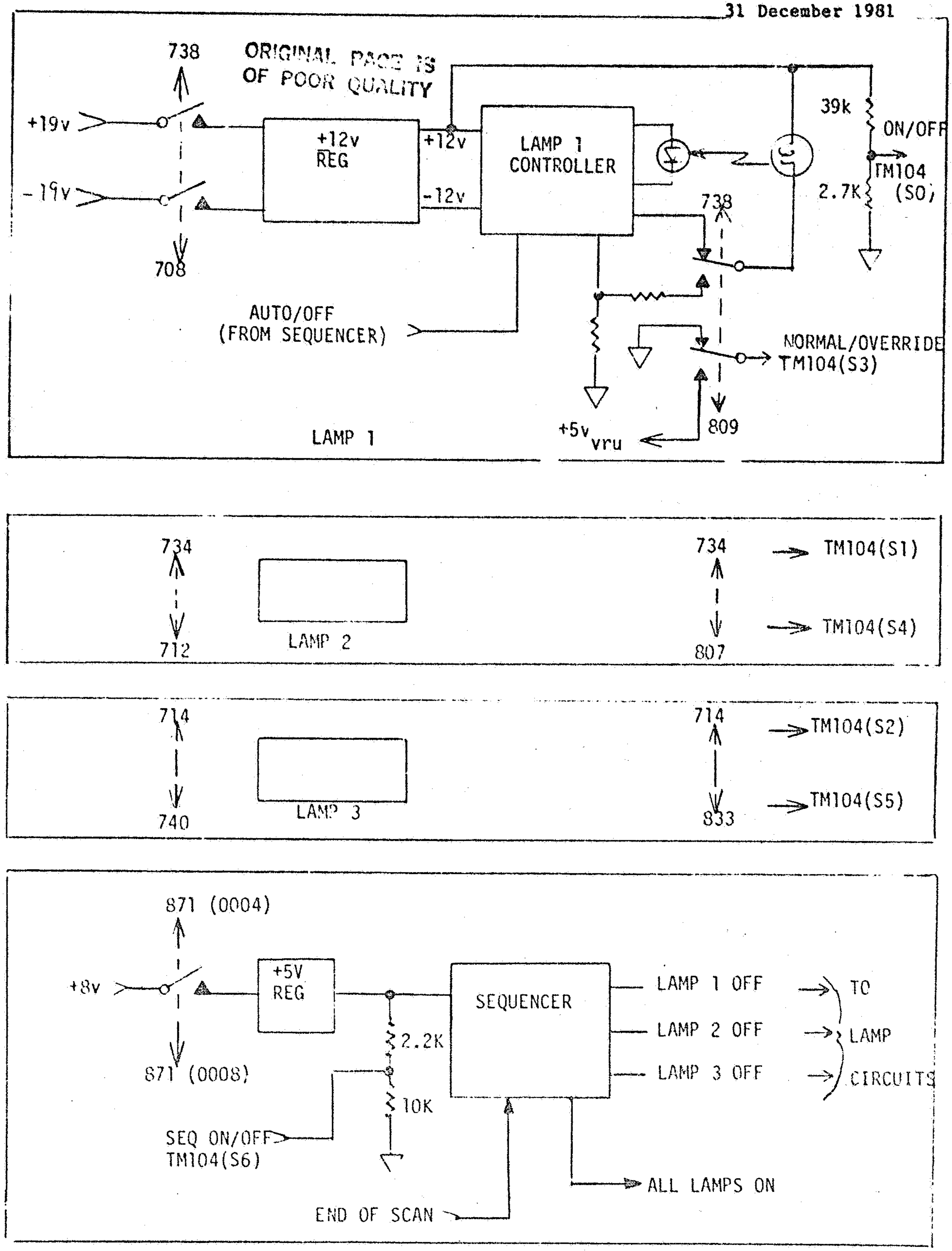

Figure 14.7-51. Calibration Lamp Status Monitor

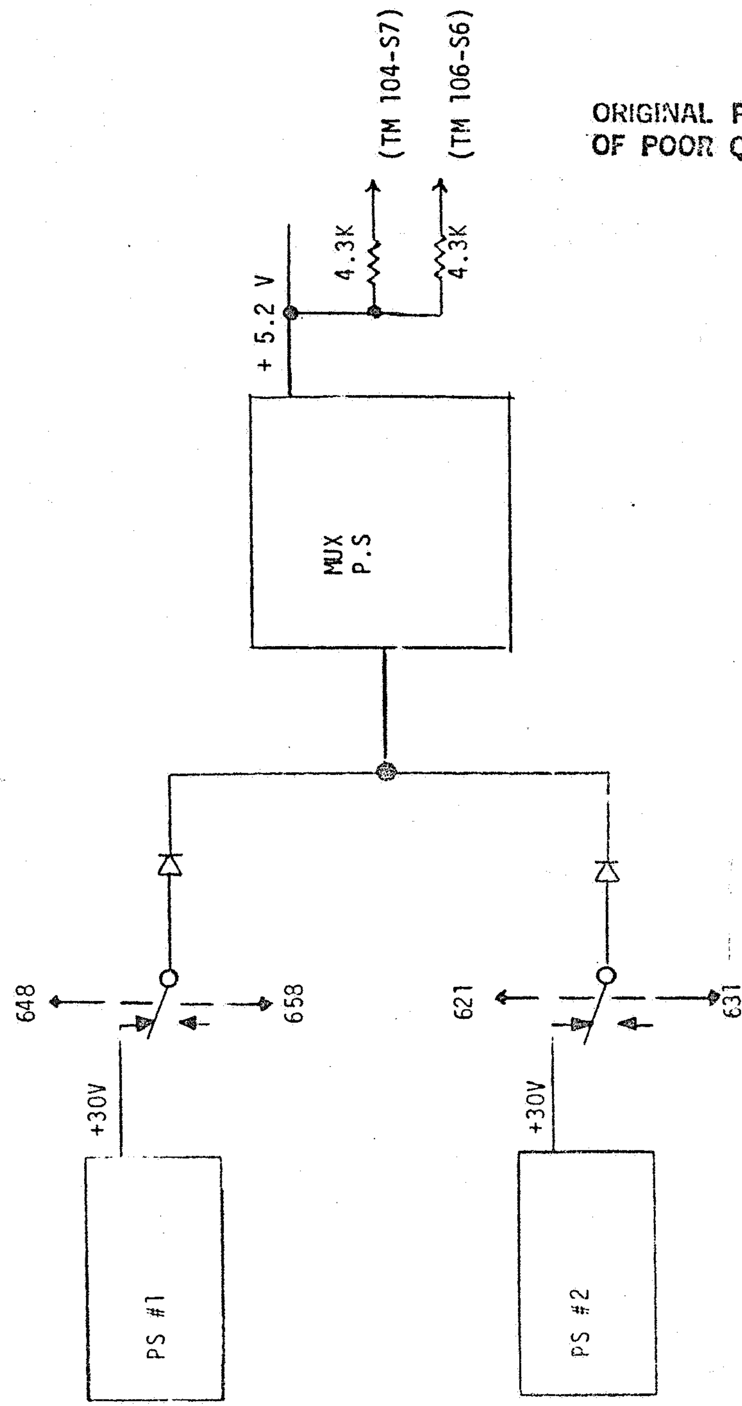

Figure 14.7-52. Multiplexer Status Monitor

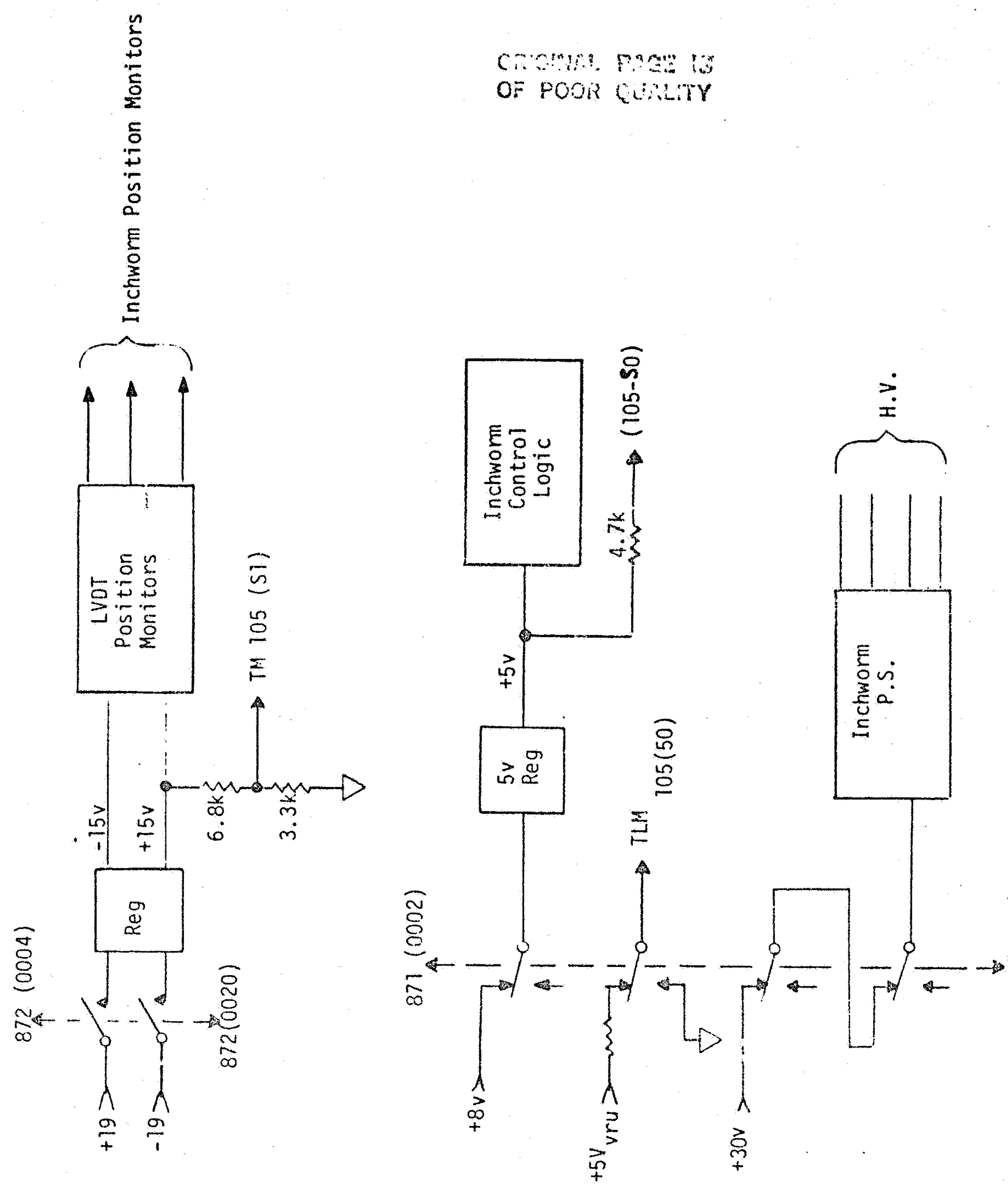

Figure 14.7-53. Inchworm Status Monitor

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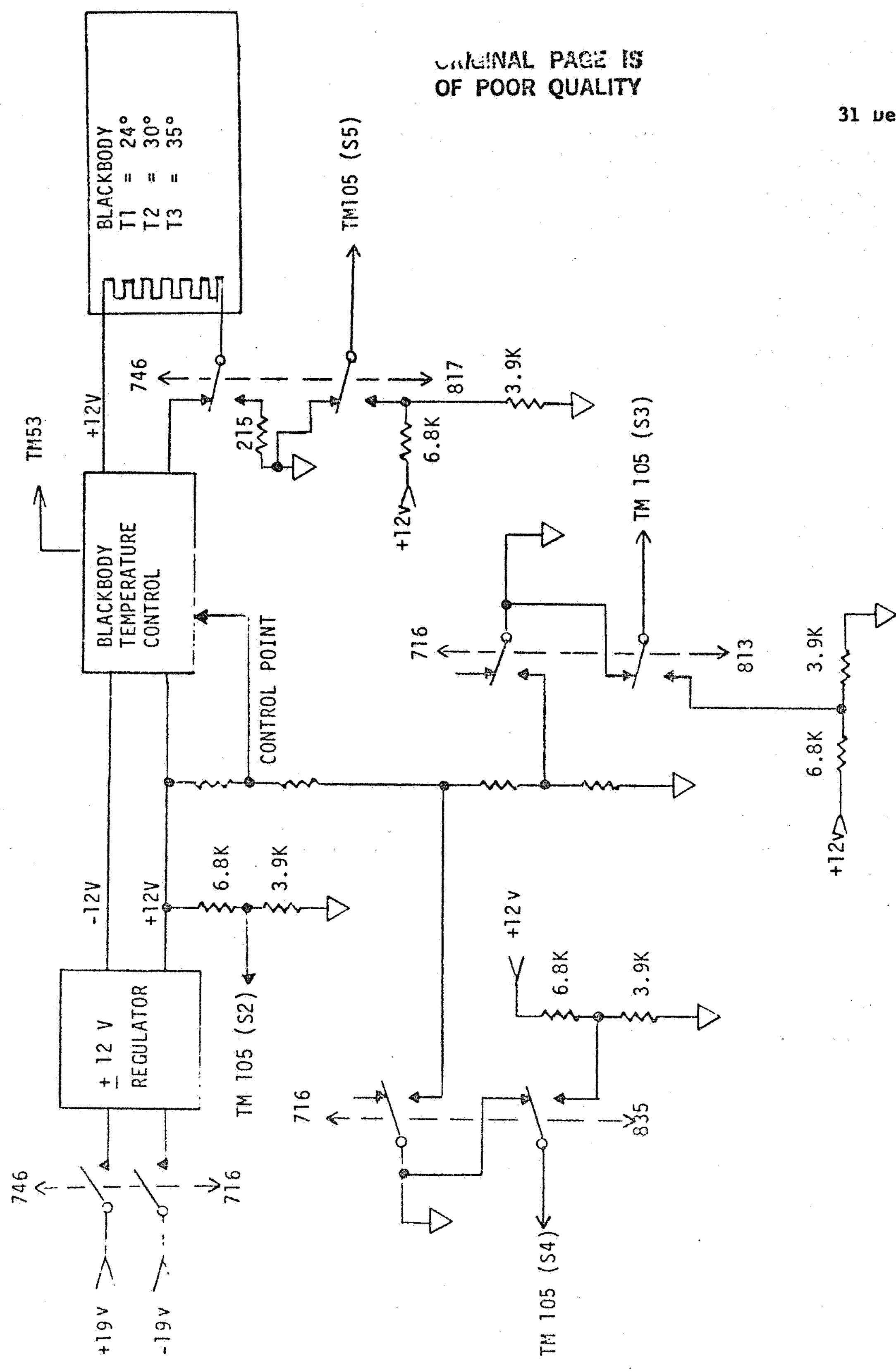

Figure 14.7-54. BB Temperature Control Status Monitor

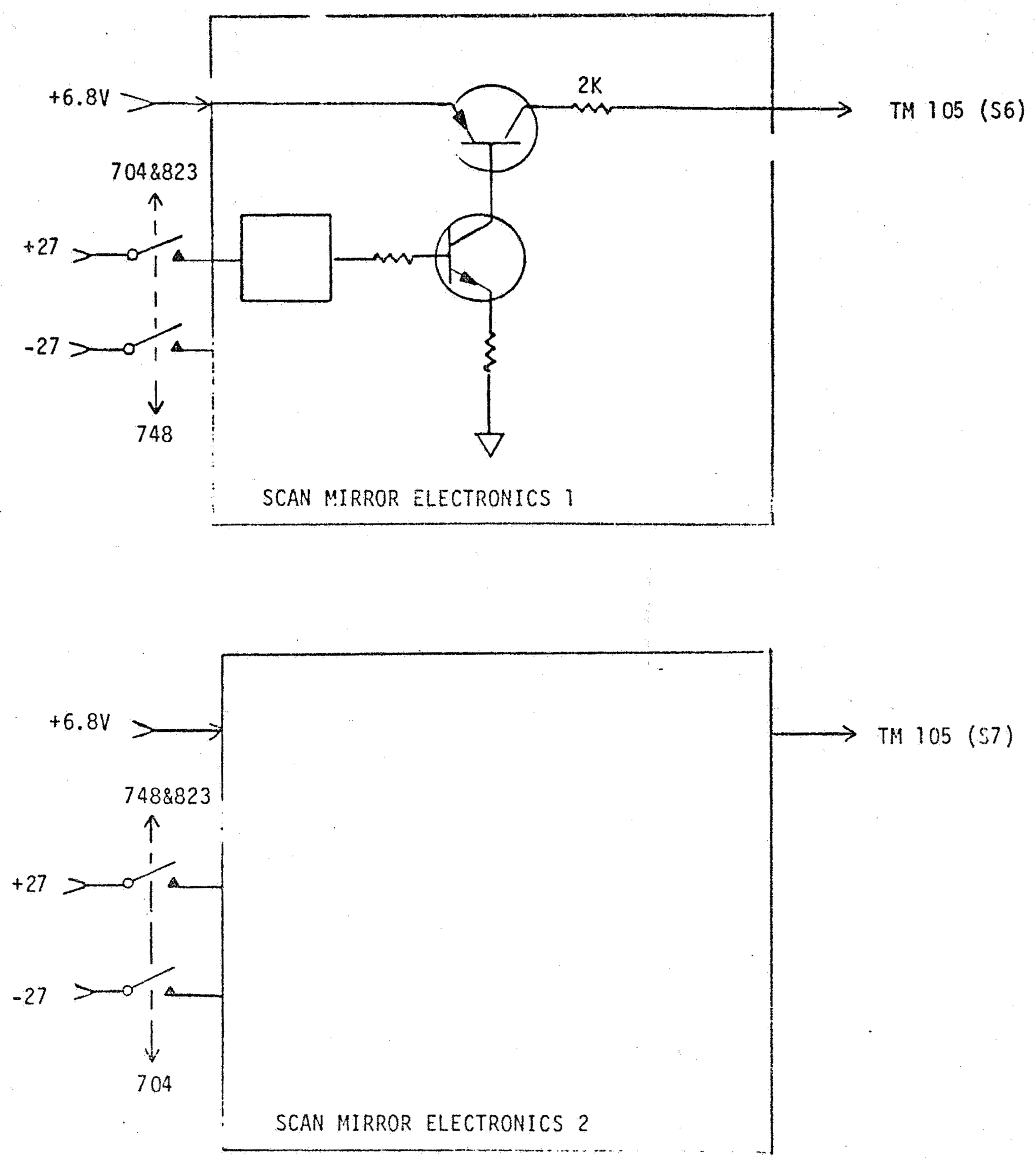

Figure 14.7-55. Scan Mirror Electronics Status Monitor

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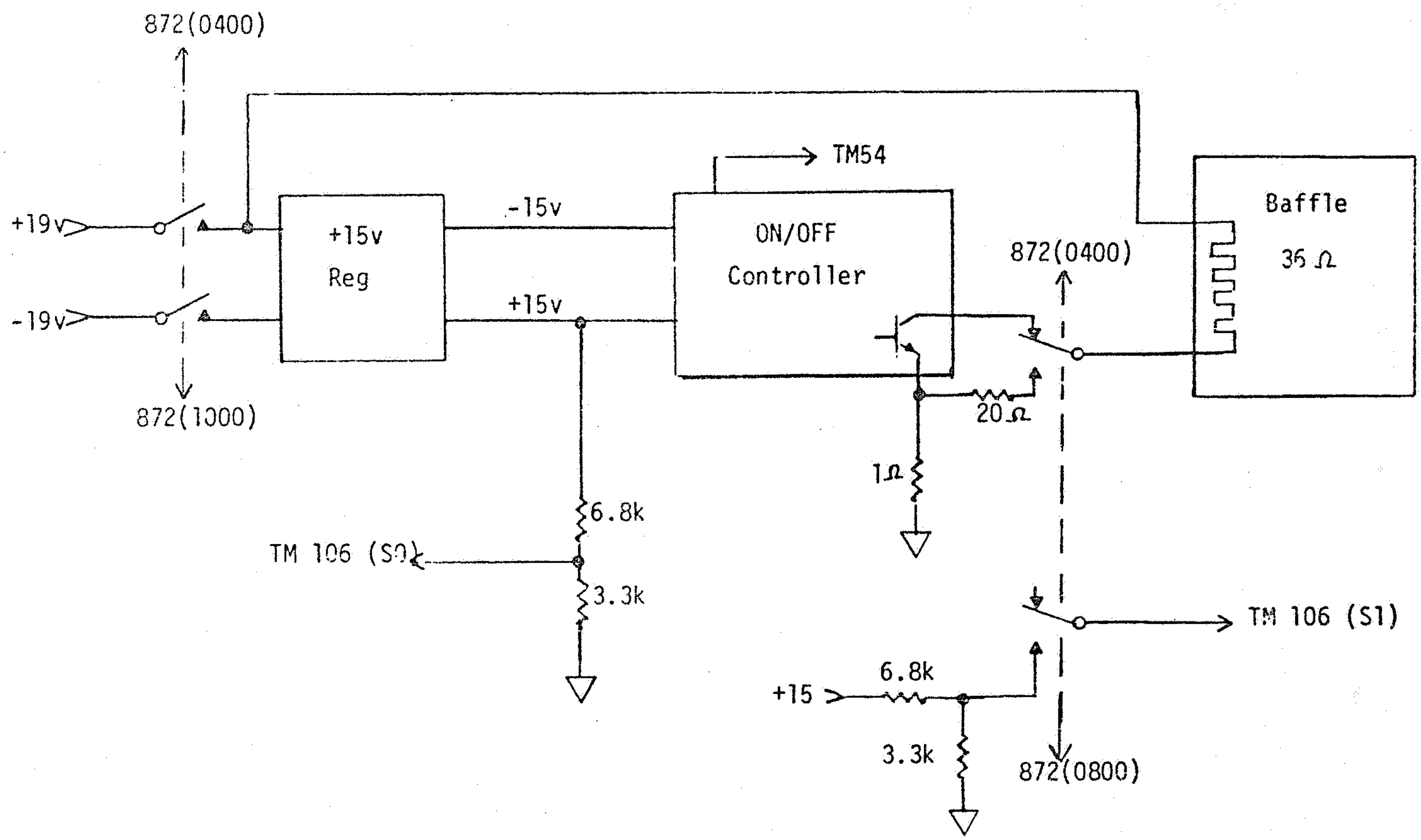

Figure 14.7-56. Baffle Heater Control Status Monitor (TBAFFHTR)

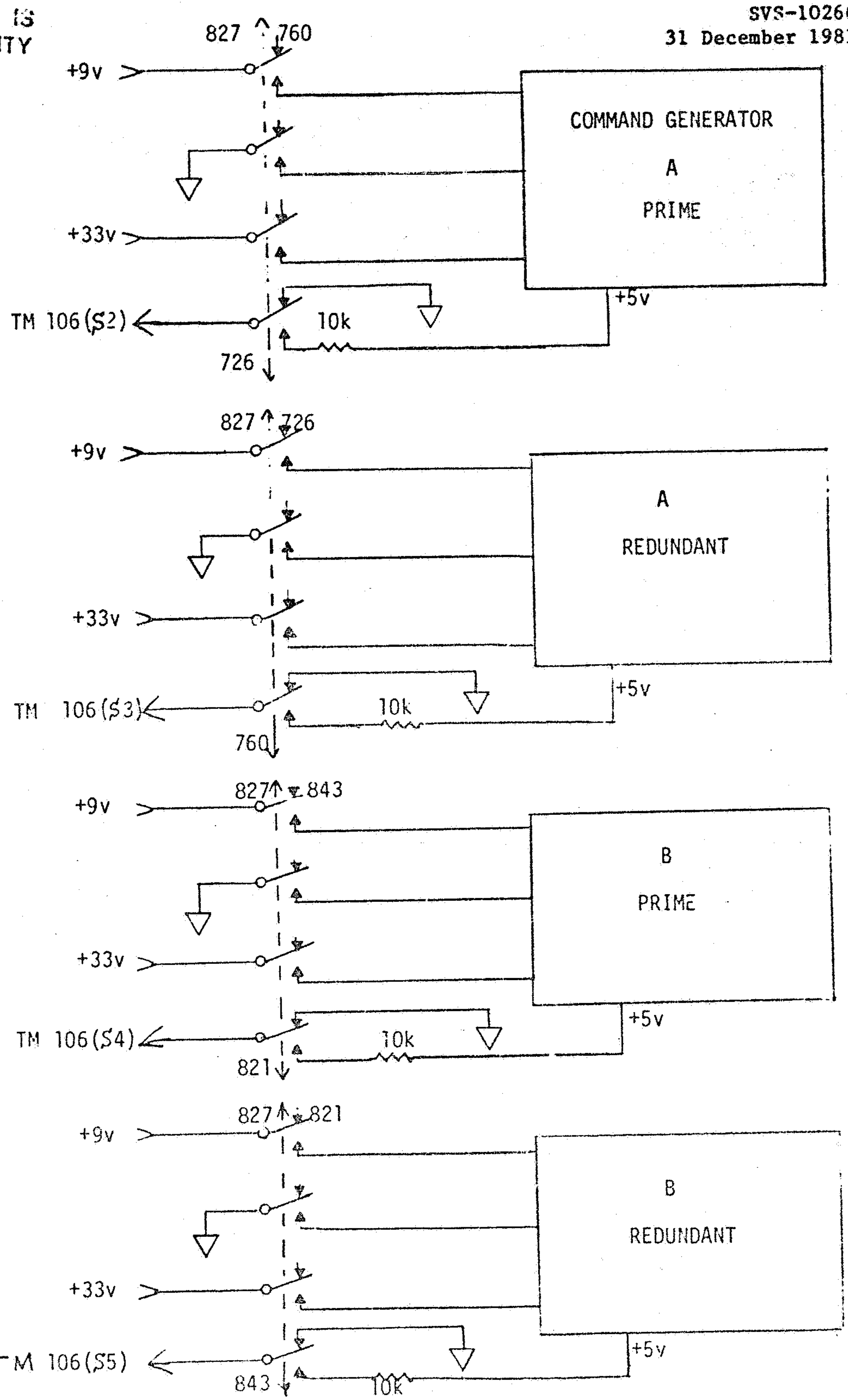

Figure 14.7-57. Command Generator Status Monitor (TMDCGSEL)

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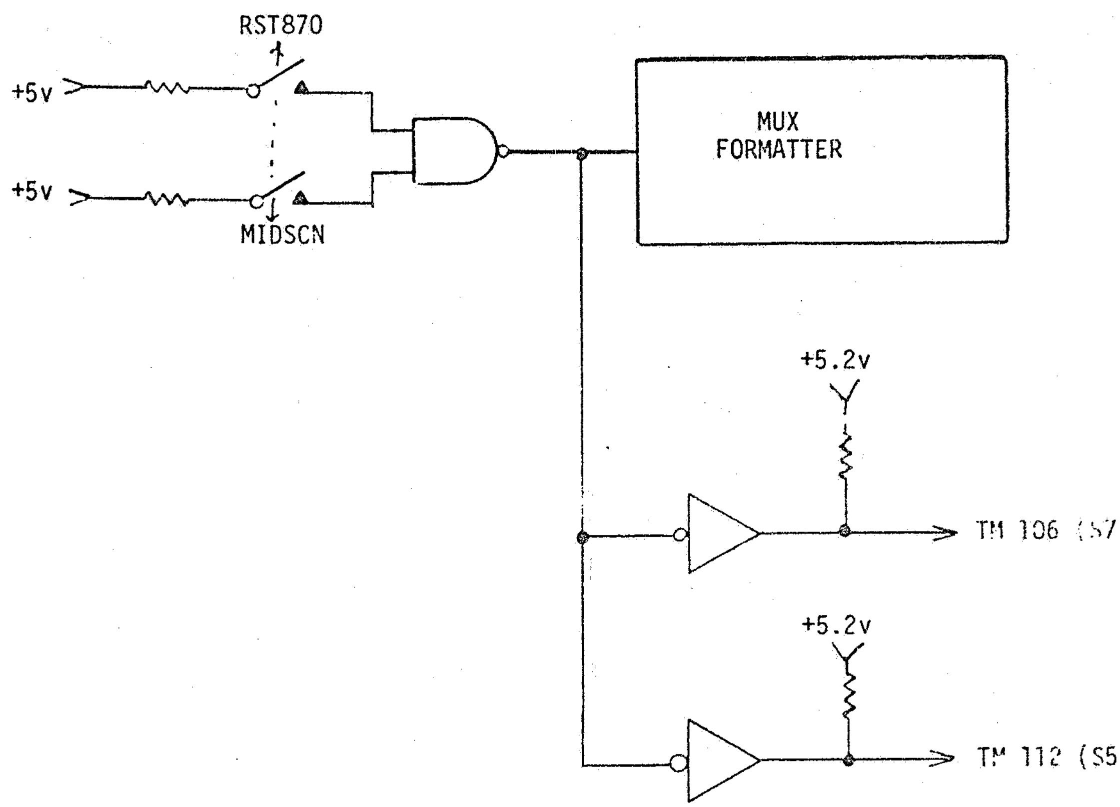

Figure 14.7-56. Mid Scan Marker Status (TMIDSCAN)

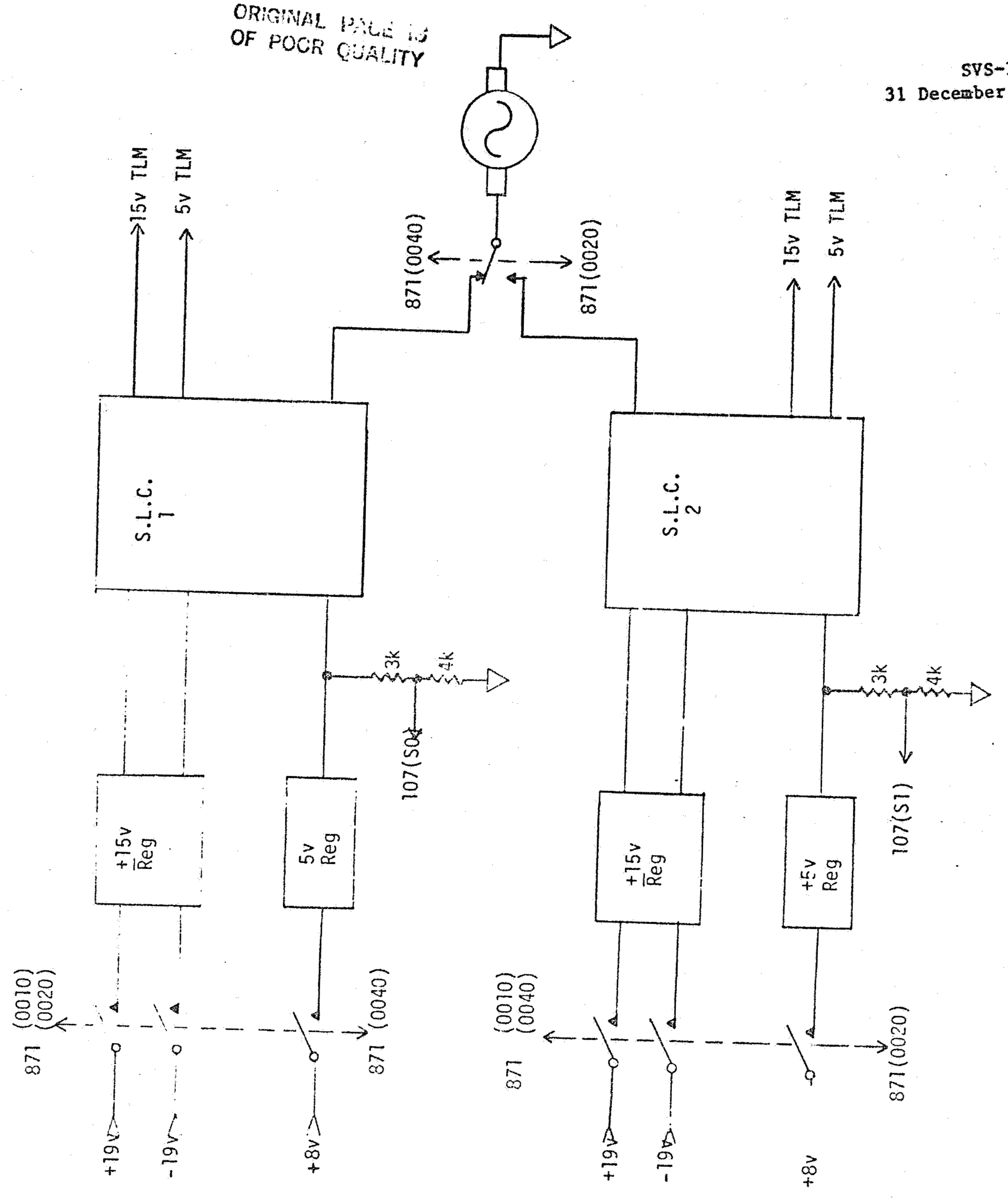

Figure 14.7 Scan Line Corrector Selection Monitor (TSLCSEL)

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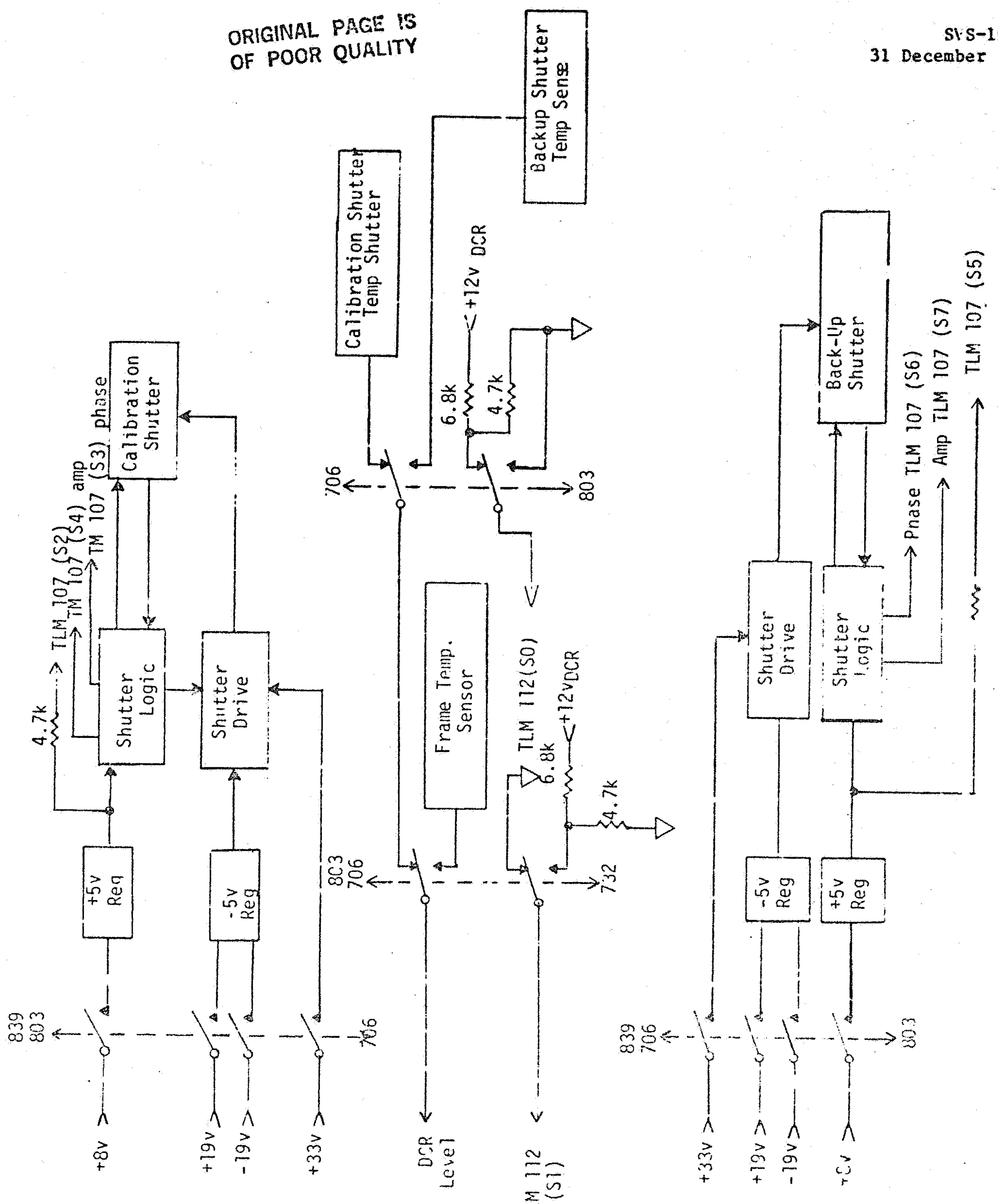

Figure 14 7-60. Shutter Status Mo (TCALSHTR, TBUSHTR, TDCRSTAT)

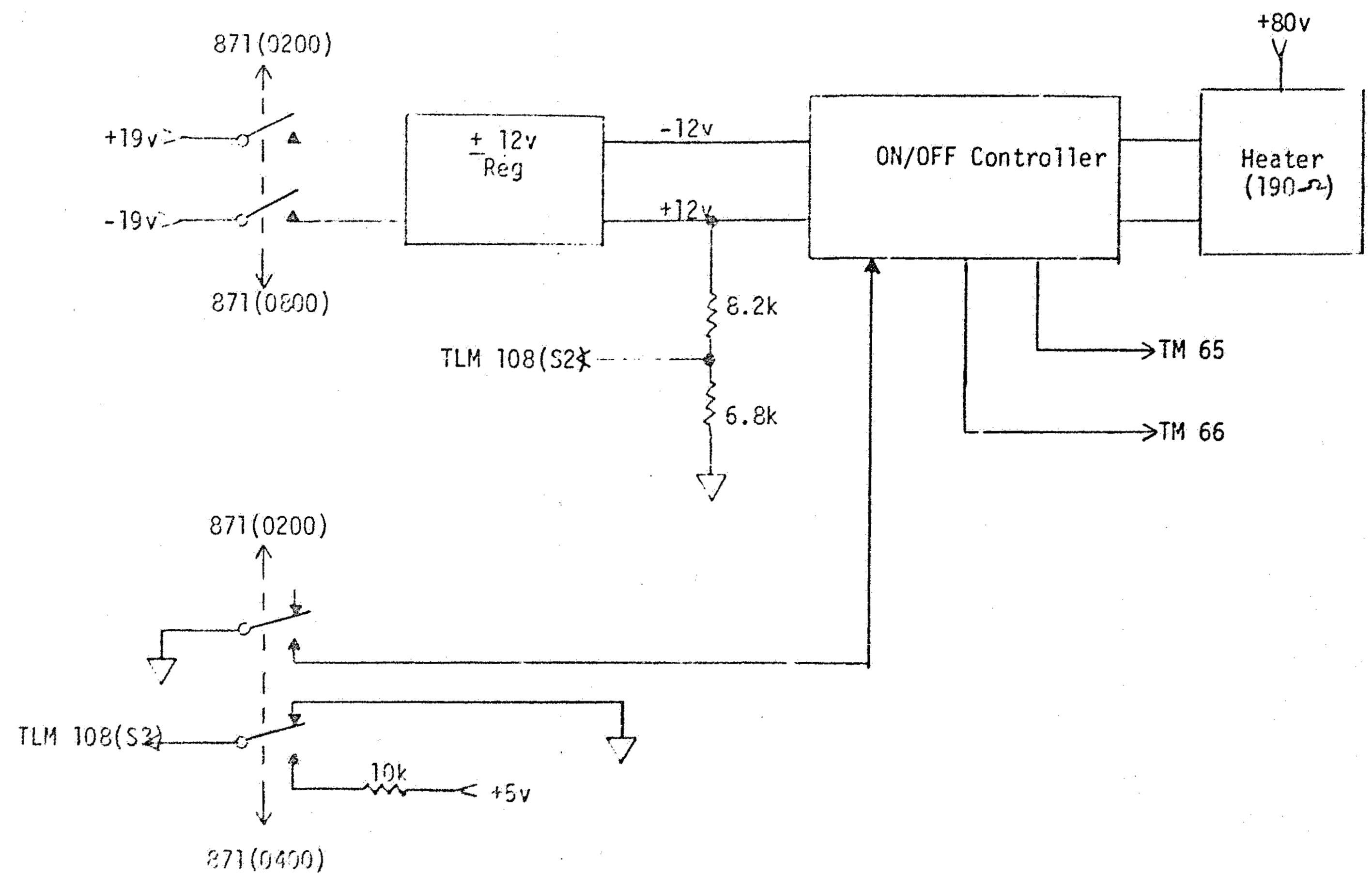

Figure 14.7-61. Intermediate Stage Heater Control Status Monitor (TISCNTRL)

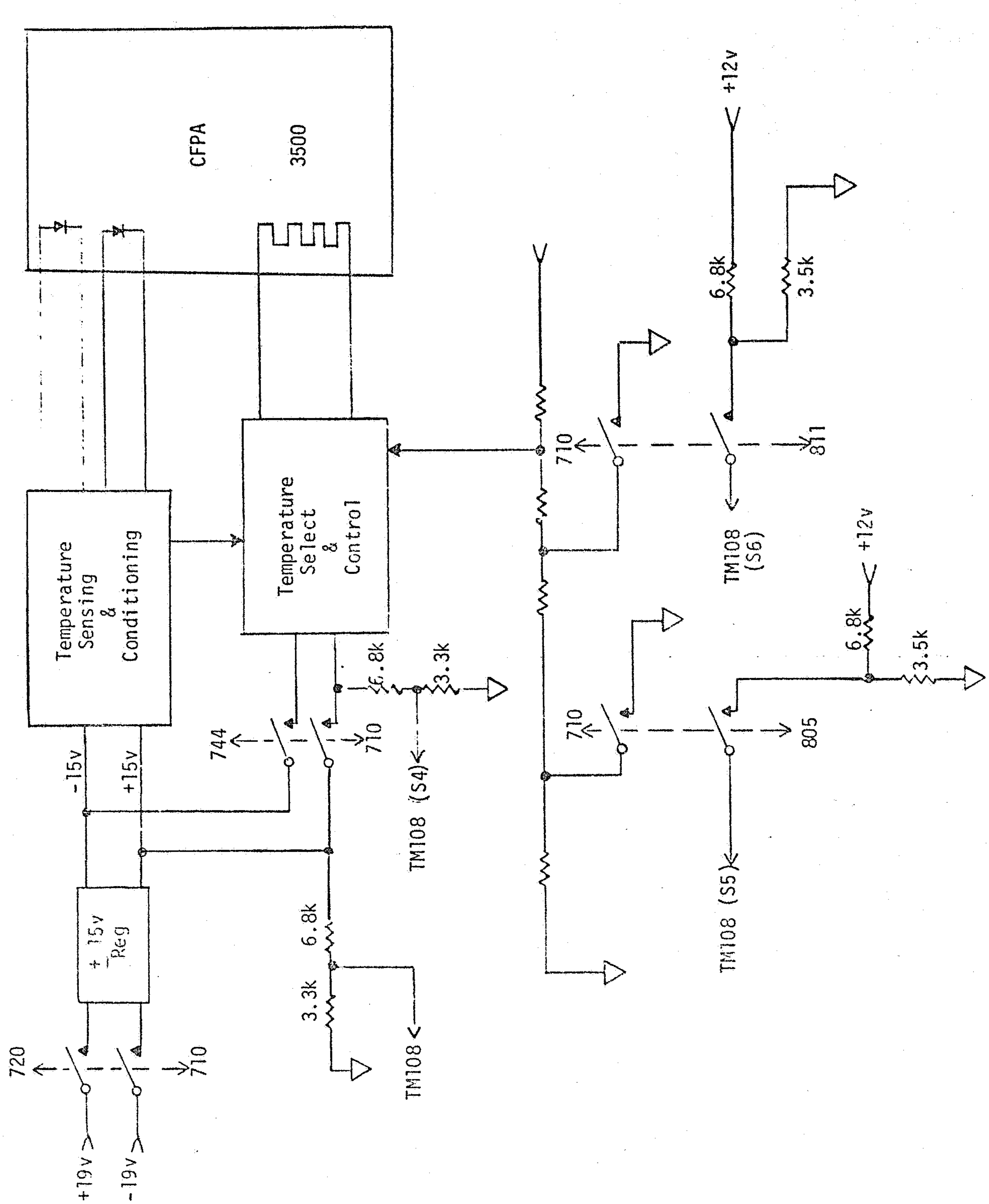

Figure 14.7-62. CFPA Temp ture Control Status Monitor (TCFPA)

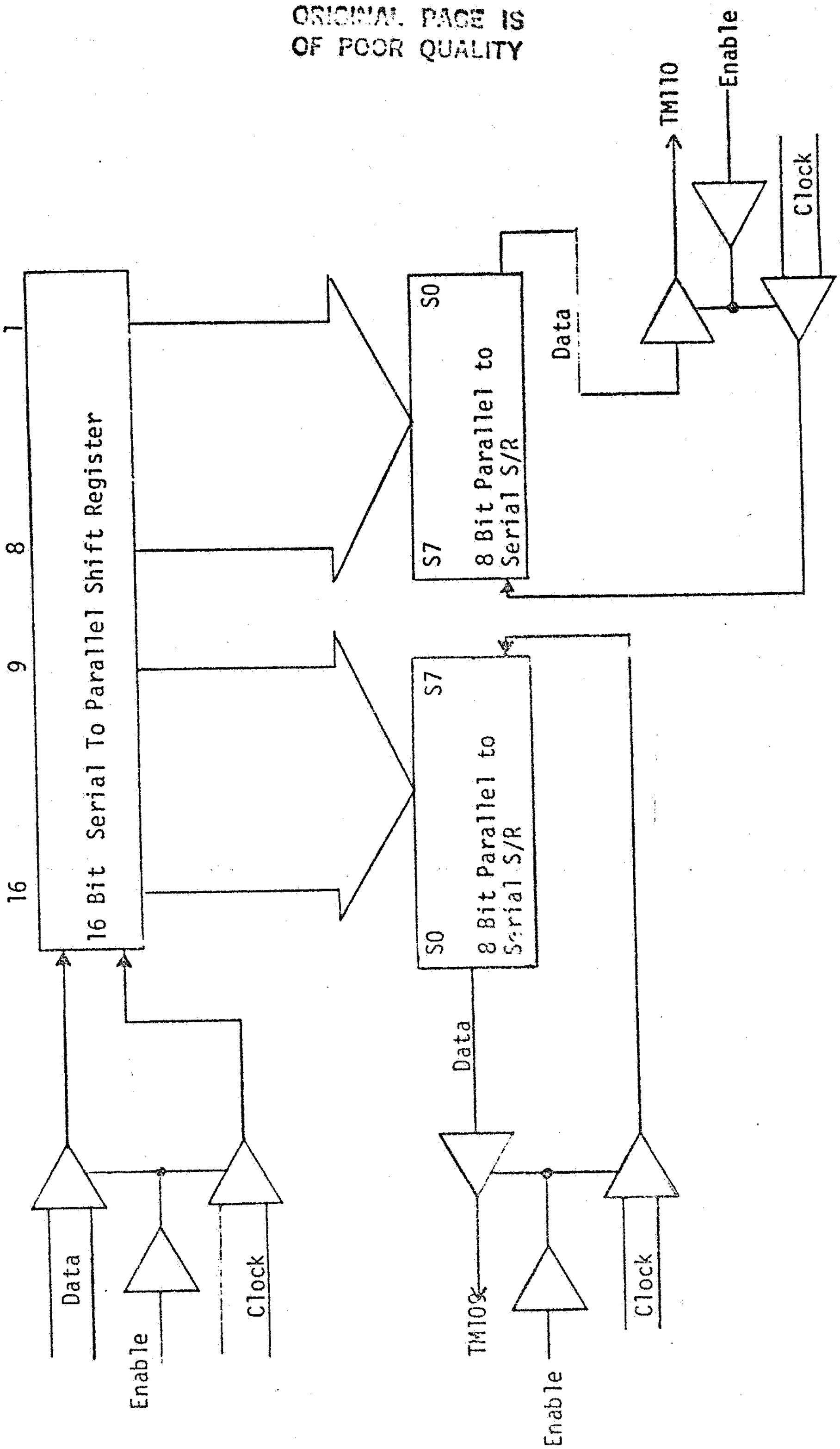

Figure 14.7-63. Command 870 Echo

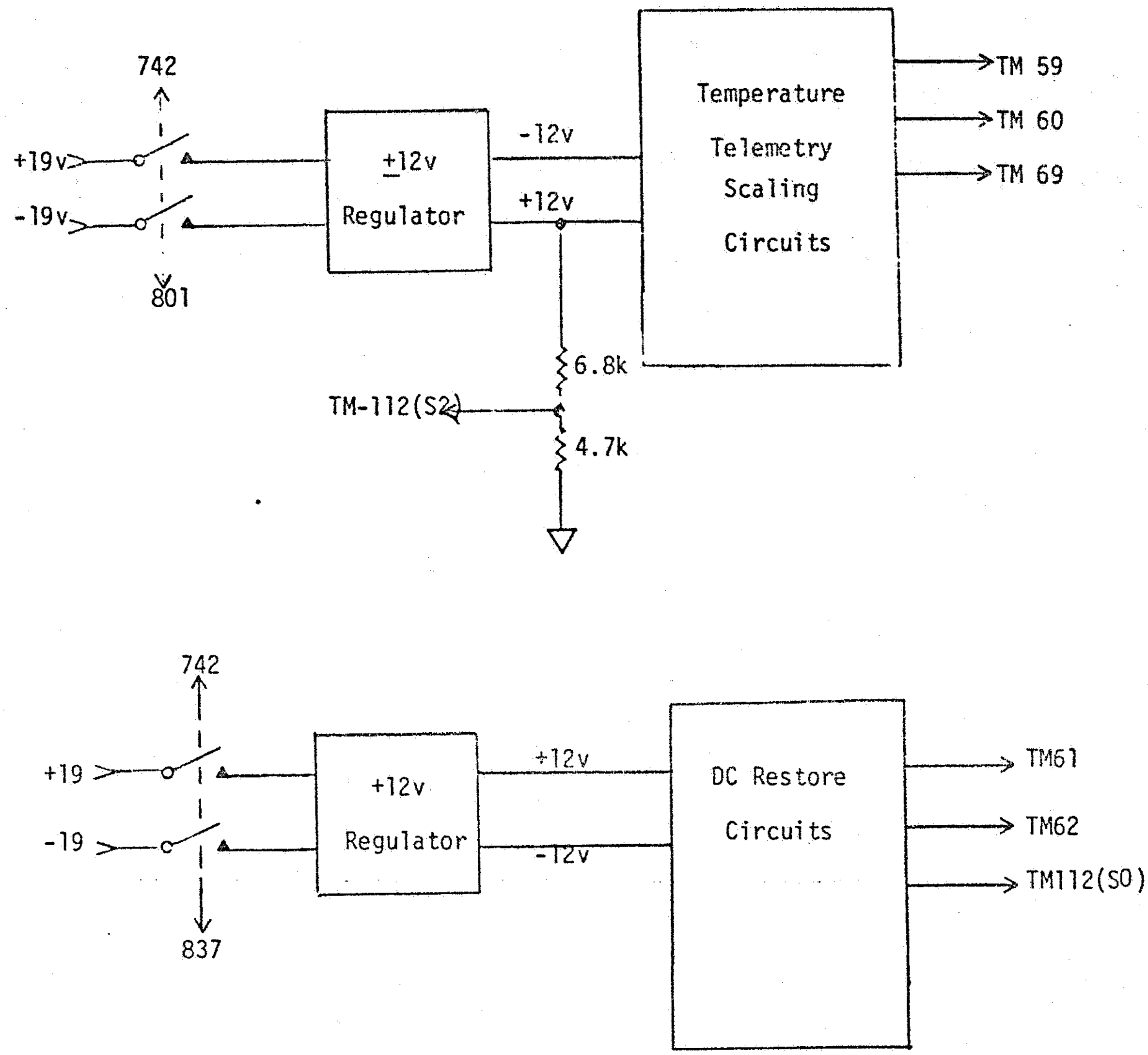

Figure 14.7-64. Telemetry Scaling - DC Restor Status Monitor (TTLMSCAL)

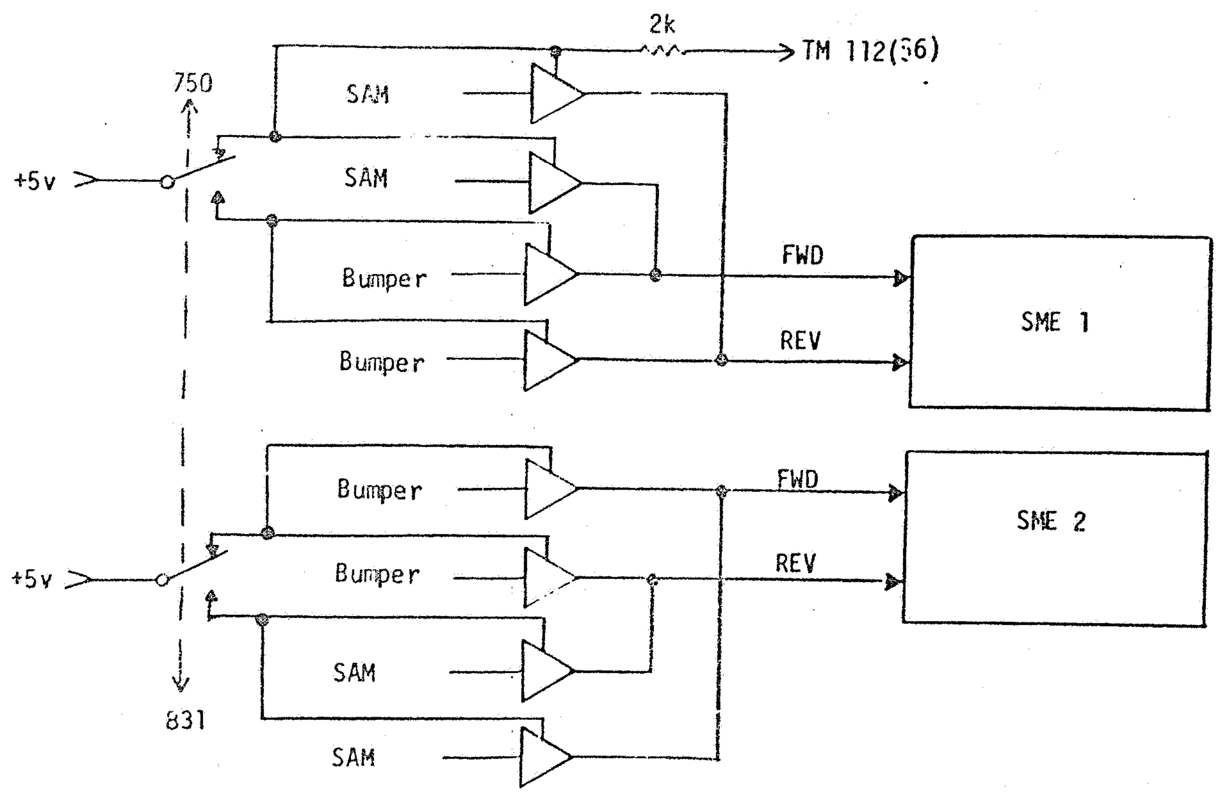

Figure 14.7-65. Scan Mirror Control Status Monitor (TSAMSEC)

15.0 GLOBAL POSITIONING SYSTEM

SECTION 15

GLOBAL POSITIONING SYSTEM

The Global Positioning System (GPS) provides the LANDSAT-D and LANDSAT-D Prime with an automatic on-board spacecraft navigation system. The GPS consists of a constellation of navigation satellites known as Navigation Development Satellites (NDS) and a GPS Subsystem located on-board the spacecraft. The GPS Subsystem processes signals received concurrently from up to four NDS's. Based upon measurements made on these signals, the GPS Subsystem computer estimates the spacecraft's three dimensional position and velocity vectors at a specific point in time. The GPS time is essentially the UTC (Universal Time Coordinated) measured in seconds since Saturday midnight at which time the GPS time is reset (presently, the GPS time is offset by UTC by 3 seconds).

All of the planned NDS's may not be in orbit when the LANDSAT-D or the LANDSAT-D Prime is launched and there may be times when no Navigation Development Satellites are in view. During the time when less than the required number of satellites are in view, the GPS Subsystem will, under software control, switch to a propagate mode; and based upon past data, propagate the current navigation solution (state) forward in time.

The GPS Subsystem periodically (nominally once every 6 seconds) outputs the current navigation state to the spacecraft Communication and Data Handling (C&DH) subsystem for use by the spacecraft on board computer (OBC). The OBC transforms the navigation updates into the proper coordinate systems which are utilized by the attitude control system, and for the computation of the high gain antenna pointing angles. The position, velocity and time data are also downlinked via telemetry for use by the ground station.

The ionosphere can affect the propagation times. The GPS satellites send the navigation data on two separate carriers referred to as L_1 and L_2 carrier frequencies. The GPS Subsystem measures the pseudorange and delta pseudorange on both the L_1 and L_2 frequency signals, estimates the error caused by the ionosphere and applies the appropriate correction factors to the L_1 carrier measurements.

Landsat-D is one of the first NASA spacecraft scheduled to carry the GPS, and a period of several months is planned for evaluation and experimenation. Ephemeris accuracies will be validated and the overall performance of the GPS Subsystem will be assessed. The GPS ubsystem will, on command, output a series of data files including a complete memory dump which in the event of contingencies, can be used for diagnostics.

15.1 GPS-SUBSYSTEM FUNCTIONAL DESCRIPTION

The GPS Subsystem consists of the components shown in Figure 15.1-1. The Receiver/Processor Assembly (R/PA) includes the processor computer which computes the navigation solution (state), controls the receiver configuration and controls the operation of the system. The following subsections describes the function of each of these components:

15.1.1 L1/L2 ANTENNA

The GPS antenna receives both the L1 and L2 frequency signals. It is mounted on the boom that supports the TDRSS high gain antenna and except for blockage due to the boom, the L1/L2 Antenna provides a general hemispherical pattern.

15.1.2 L1/L2 PREAMPLIFIERS

The dual channel preamplifier filters the L1 and L2 frequency signals and provides front-end gain. It consists of two preselection RF filters each followd by a low noise RF amplifier. The L1 and L2 frequency signals are electrically isolated in the preamp and recombined to form the input into the Splitter.

15.1.3 REFERENCE OSCILLATOR

The reference oscillator is an ultra-stable oscillator similar to the Communications & Data Handling Subsystem (C&DH) external oscillator. The GPS Subsystem Oscillator provides the precision master 5.115 MHz frequency signal source used throughout the GPS Subsystem for frequency synthesizes and timing. Even though there are commands to select either oscillator #1 or #2, there is only one GPS Subsystem oscillator aboard Landsat-D or Landsat-D Prime and it is referred to as oscillator #1.

The oscillator telemetry parameters consist of oven temperatures, oscillator case temperatures, regulator voltages and heater voltages.

The oscillator requires about 2 hours to stabilize prior to entering a navigation mode.

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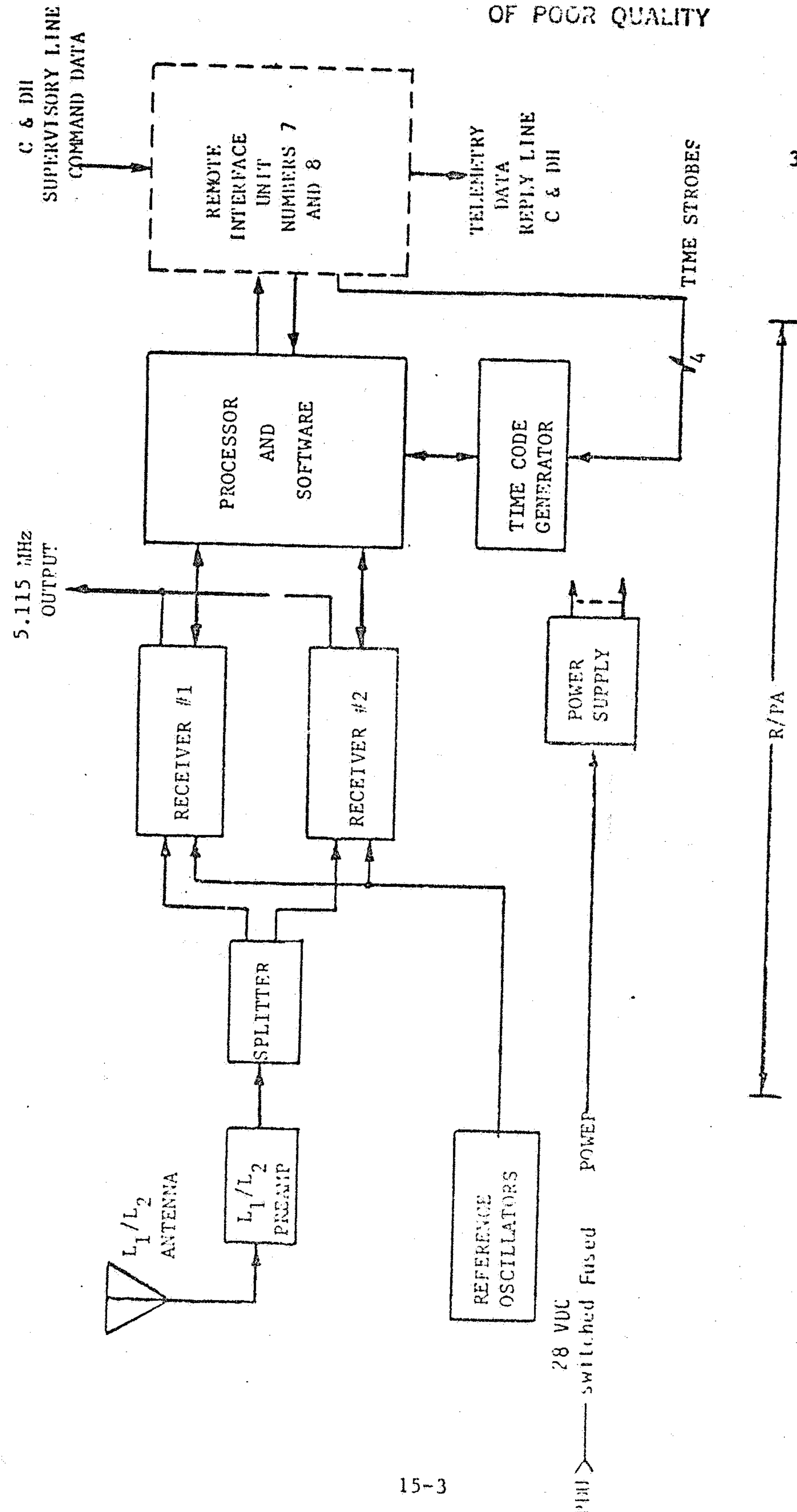

Figure 15.1-1. GPS Subsystem: Components & Interfaces

15.1.4 GPS SUBSYSTEM RECEIVERS

The R/PA contains two Receivers either of which can track signals from a particular NDS. Each receiver is a triple-conversion, single VCXO design which contains a carrier tracking (COSTAS) loop, a code tracking loop and the data detection (demodulation) circuitry. Also, each receiver contains its own frequency synthesizer which inputs the 5.115 MHz Reference Oscillator signal and generates all of the single frequency signals required for frequency conversion.

The GPS Receivers are phase detectors and the receiver functional description starts with a definition of the intrensic properties of the signals to be processed (locked onto and tracked). NDS transmit two navigation signals: A Primary Navigation Signal which is transmitted on the L1 frequency carrier and a Secondary Navigation Signal which is transmitted on the L2 frequency carrier. The L1 signal is a composite wave made up of a Precision (P) Signal and a Coarse/Acquisition (C/A) Signal. Both the P-Signal and the (C/A) Signal are transmitted simultaneously on the L1 carrier and one or the other is transmitted on the L2 carrier. The system navigation data are transmitted at all times on both the L1 and L2 frequency carriers.

The P-Signal is a continuous sinusoidal wave that is biphase modulated according to the Modulo-2 sum of a PN code and a synchronous data bit stream. At any point in time, each NDS will transmit a unique P-Code. The (C/A) Signal is a continuous sinusoidal wave that is in quadrature with the P-Signal. It is biphase modulated with the Module-2 sum of a 1023 bit Gold code sequence and a synchronous data bit stream. One of the 36 unique codes within the 1023 bit Gold code will be used as the (C/A) signal.

The receiver processing function (software) monitors the receiver operation and performs the receiver control functions. It controls the receiver hardware modes required to do the following: search, detect, pull in and track the signal transmitted by a particular Navigation Development Satellite. It also assembles the hardware demodulated 50 bps data into raw 30 bit data words.

The R/PA Processor memory retains the almanac data for the spacecraft and for each NDS. The initial almanacs are uplinked by R/PA Data Command Messages. See Paragraph 15.6, Command Processing which defines the commands used to upload the initial almanacs.

The GPS measures the distance and velocity of each NDS relative to the GPS Subsystem on-board the spacecraft; and based upon these measurements, th GPS subsystem estimates the Spacecraft's position and velocity at a specific point in time. The pseudorange and delta pseudorange are the measurements before the time clock correction.

The GPS Receiver acquires the signal from the selected NDS as follows: Initially the Processor, based upon the almanacs stored in memory, computes the pseudorange and delta pseudorange for the selected satellite. The receiver uses this information to pre-position the receiver VCXO to the expected doppler and doppler rate.

The receiver can acquire an NDS signal when the initial expected values are as gross as 200 km and 200m/s (3-sigma error). The initial clock value stored (set) in the Time Code Generator by R/PA Data Command can be as gross as 2 seconds when the discrete command TCG Run is issued.

The receiver searches the uncertainty region until it obtains a carrier lock and a clear (C/A) code lock is detected. The receiver includes an AFC loop which speeds up the initial carrier search.

Once the Receiver acquires an NDS, the R/PA collects precise ephemeris information for the acquired NDS and can, if necessary, collect less precise almanacs for other satellites in the NDS constillation. Following P-code lock and bit sync, the ephemeris, time correction, almanac and health status are all read into the processor. The Almanac Collection is controlled by R/PA Data Command Message as follows:

1. Permanent Collection - continues to read NDS almanac data until commanded OFF (Receiver Test Mode only).

2. Temporary Collection - continues to read NDS Almanac data until a complete new almanac is collected (all navigation modes except the Receiver Test Mode).

3. Periodic Collection - continues to read NDS almanac data until a complete new almanac is collected at N hour intervals - not less than a three hour interval (Space Mode Only).

During normal operation, the complete NDS almanac is automatically updated once a week.

This completes the description of the housekeeping function. The Receiver's function to measure the pseudorange and delta pseudorange used to update the Spacecraft Navigation State are considered next.

The two GPS receivers can be used either singlely or together. The receivers consume about 40 watts in the dual channel mode and about 32 watts in the single channel mode. During normal operation only one receiver is powered and the L1 and L2 measurements are made sequentially as shown in Figure 15.1-2. In this mode, the R/PA dwells for six seconds on each NDS with approximately half of the time spent on each frequency. However, in three seconds the spacecraft will have moved along its track and the ionospheric conditions could have changed slightly. Consequently, both receivers can be powered and the L1 and L2 frequency measurements made simultaneously, see Figure 15.1-3. The dual receiver mode provides more accurate ionospheric corrections at the expense of about 8 watts of power.

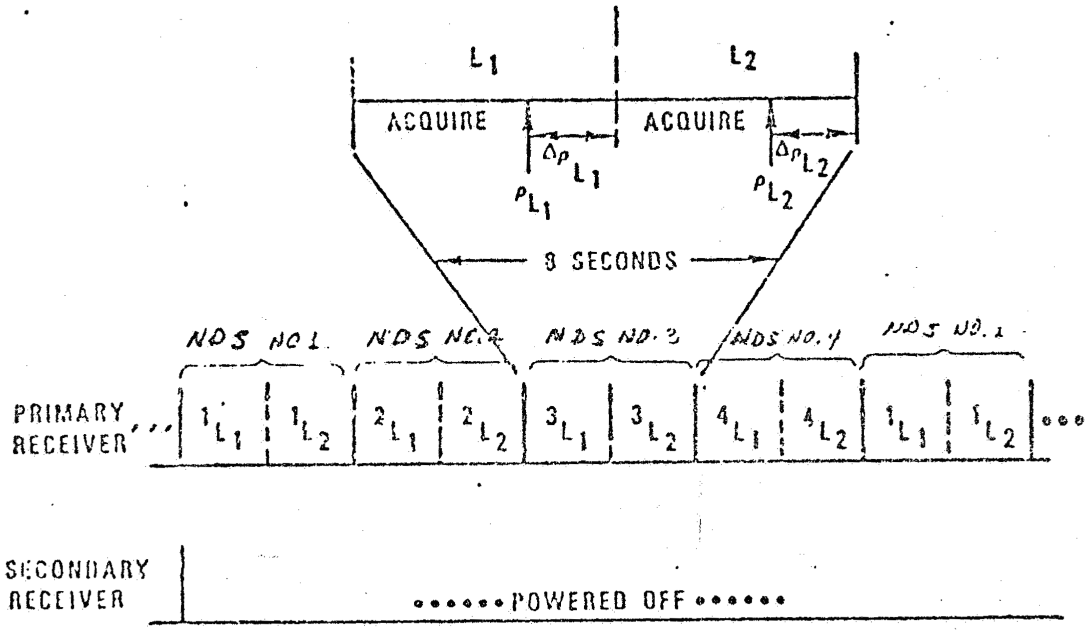

Figure 15.1-2. Single Channel NDS Sequential Track

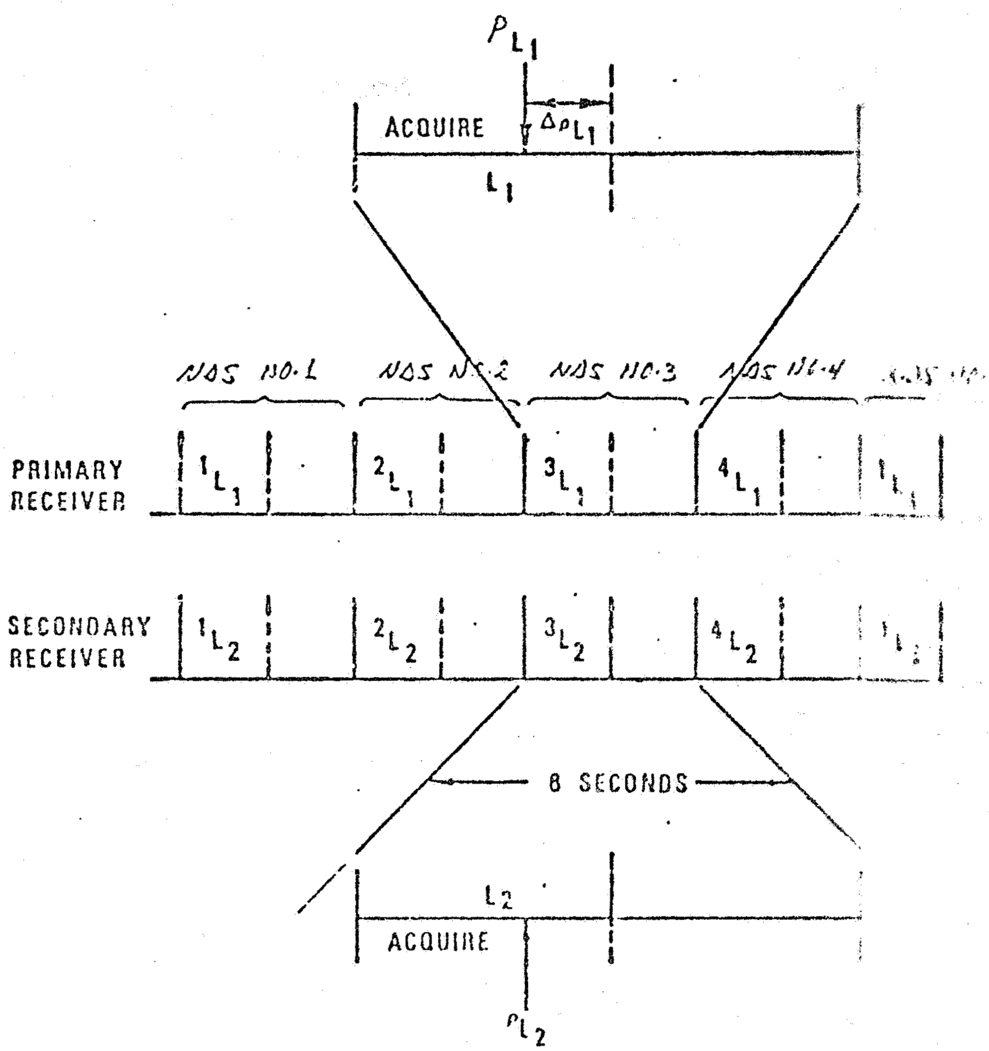

Figure 15.1-3. Dual Channel NDS Sequential Tra...

3. Management of the dual channel receiver hardware to [illegible] acquire and track NDS signals based on uplinked information and estimates of current and predicted NDS and Landsat-D positions. [illegible] channel of the receiver is selected by command as the primary [illegible] the other (if selected) is the secondary channel. [illegible] navigation data are obtained from the primary channel. [illegible] measurements of pseudo range and delta pseudorange are [illegible] any selected channel.

15.3.2.3 Almanac Collect Mode Processor

The R/PA processor requires an almanac for both the Spacecraft [illegible] Navigation Development Satellite before it can acquire the [illegible] Landsat-D Almanac is uploaded by R/PA Data Command type 5 and the [illegible] are initially uploaded by R/PA Data Command type 6. Each [illegible] almanac for all Navigation Development Satellites, and the NDS [illegible] obtained by demodulating the signal from the NDS currently being [illegible]

15.3.2.4 Sequential Track State Processor

Each NDS continuously transmits information on both the [illegible] frequencies. The sequential track state processes the two carrie[illegible] In this state the monitor controls the fixed dwell times used for [illegible] of NDS signals; provides regular telemetry using the tele[illegible] function; the BIT background self test loop regularly checks sys[illegible] the monitor regularly invokes the satellite selection function [illegible] up to four NDS satellites that are to be used concurrently by [illegible] function.

Navigation state: When the GPS Subsystem is tracking the [illegible] number of satellites, the receiver measures the pseudorange [illegible] pseudorange. The navigation function reads the available [illegible] updates the navigation state.

15.4 CONSTRAINTS GPS-SUBSYSTEM

1. The GPS-Subsystem has only one Reference Oscillator [illegible] called for in the literature. The Discrete Pulse [illegible] Select Oscillator #2 should not be used since the Osci[illegible] included in the LANDSAT-D or LANDSAT-D Prime GPS Subsy[illegible]

```
BIT  15 14 13 12 11 10 9  8  7       0
     +--+--+--+--+--+--+--+--+--------+
     |  |  |  |  |  |  |  |  |        |
     +--+--+--+--+--+--+--+--+--------+
      |  |  |  |  |  |  |  |  |
      |  |  |  |  |  |  |  |  +---Interrupt Mask Register
      |  |  |  |  |  |  |  |           (Read/Write)
      |  |  |  |  |  |  |  |
      |  |  |  |  |  |  +---------Bank Select Bits
      |  |  |  |  |  |             • 0=Locations 60000-157776
      |  |  |  |  |  |                are assigned to Bank 0
      |  |  |  |  |  |             • 1=Locations 60000-157776
      |  |  |  |  |  |                are assigned to Bank 1
      |  |  |  |  |  |             • 2=Locations 60000-117776
      |  |  |  |  |  |                are assigned to Bank 2
      |  |  |  |  |  |             (Read/write, not used without
      |  |  |  |  |  |                  memory banking)
      |  |  |  |  |  |
      |  |  |  |  |  +-------------Tick control bit
      |  |  |  |  +----------------Primary channel select control
      |  |  |  |                   Setting this bit selects which
      |  |  |  |                   frequency synthesizer from one
      |  |  |  |                   of two channels is to be used to
      |  |  |  |                   drive the clocks and epoch pulses
      |  |  |  |                   for the ICS.
      |  |  |  |                      0 = Channel 1
      |  |  |  |                      1 = Channel 2
      |  |  |  |                      (read write)
      |  |  |  |
      |  |  |  +-------------------IDP Lock-Out Bit
      |  |  |                      • 0=IDP not locked out
      |  |  |                      • 1=IDP locked out
      |  |  |                      (Read/Write)
      |  |  |
      |  |  +----------------------IDP Interrupt Bit
      |  |                          Setting this bit to a '1'
      |  |                          causes an interrupt in the
      |  |                          IDP (Read/Write)
      |  |
      |  +-------------------------Spare
      |
      +----------------------------Power Fail Restart Bit
                                   • 0=Power Restart
                                   • 1=Power Fail
                                   (Read only)
```

Figure 15.1-4. System Status Word

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```
+---------------+      128 Words
| I/O Addresses | 32K
+---------------+
|               |
|               |
|               |
+---------------+ 28K  +--------------+      +----------+20K
|               |      |              |      |          |
|               |      |              |      |          |
|               |      |              |      |          |
|    Memory     |      |    Memory    |      |  Memory  |
|    Bank 0     |      |    Bank 1    |      |  Bank 2  |
|               |      |              |      |          |
|               |      |              |      |          |
|               |      |              |      |          |
|               |      |              |      |          |
|               | 16K  |              |      |          |
|               |      |              |      |          |
|               |----+ |              |      |          |
|               |    | |              |      |          |
+---------------+ 12K| +--------------+12K   +----------+12K
|               |    |
|               |    |
|               |    |
|Program Memory |8K**|
+---------------+    |
|               |    > Stack limit *
|               |    |
|               |    |
|               |    |
|               |    |
|               |    |
+--------------------+
|  Vectors      |  128 words
+---------------+  0K
```

* The stack limit is a programmable address in the lower 16K word address range. The permissible stack limit address is from 400-77760 octal.

When stack overflow detection is enabled a timeout trap will result only when a read or write operation is performed that refers to the 20 octal locations starting at the stack limit address.

** 8k boundary is the start of program memory. This includes all memory (including banked) with higher addresses, except the I/O area.

Figure 15.1-5. Memory Map

4. Navigation filter processing which inputs the measurements on a number of NDS and forms an optimized estimate of the spacecraft's position vector and velocity vector at a specific point in time.

5. Downlink transmission of system output telemetry including Landsat-D position, velocity and NDS system time, time code generator (TCG) information, pseudorange and delta pseudorange measurements, and status information, all at intervals selectable by command.

6. BIT (Built In Test function) diagnosis that includes processor CPU and memory testing and reporting.

15.2.2 GPS PROCESSOR SOFTWARE REQUIREMENTS

The R/PA software is required to perform the following twelve functions:

1. System Monitor: The R/PA system monitor controls the following: 1) The orderly transiton between the various R/PA subroutines, 2) The NDS selection function determines which satellites are in view and selects the best combination of satellites to process, 3) Demodulates the NDS telemetry data blocks for data collection, 4) Error recovery when the R/PA fails to acquire a scheduled satellite signal, and 5) the sequences required to acquire and track a selected satellite.

2. Command processing: When the R/PA enters Command Mode, the command processing function accepts R/PA Data Commands used to upload the information required to initialize the R/PA control function and to load data in the R/PA processor memory.

3. Telemetry processing: Telemetry processing function transmits the critical telemetry to the spacaecraft C&DH subsystem. The R/PA generates a series of data files which contains additional data on the R/PA operation. Upon request by previously uploaded Data Command, the telemetry function outputs to telemetry any previously requested Serial Data Files.

4. Receiver processing: The receiver processing routine sets the receiver hardware configuration, controls the VCO frequency, enables the hardware control loops, and monitors the receiver hardware as required to acquire and track selected NDS signals. It computes pseudorange and delta pseudorange corrected for ionospheric conditions and as required demodulates the NDS telemetry data.

5. Satellite Data Collection: The Satellite data gathering function collects the ephemeris and almanac data as received from the current NDS telemetry. It also provides GPS clock correction data and parity checking during the collection of NDS telemetry.

6. Navigation function: The navigation function accumulates all NDS measurement data and provides a Kalman filter best estimate of the LANDSAT-D's position and velocity at a specified point in time. This processing occurs after each new NDS measurement.

7. Satellite selection: The R/PA receiver can process concurrently up to four NDS signals. The satellite selection function, based upon available almanac data, selects the best combination of Navigation Development Satellites to be used in the navigation solution.

8. Built-In Test: The Built-In Test function provides the power-up sequences for the R/PA software, error interrupt processing and background self-test that verifies critical memory.

9. Executive program: The executive programs is a multitasking program that schedules the system tasks to be performed.

10. Satellite position: The satellite position computation function reads the NDS almanac data and computes the relative position of the NDS.

11. Time Code Generation: The TCG processings detects the occurance of events that require time code; and based upon the 45 bit TCG, determines the time the events occurred.

15.3 GPS SUBSYSTEM MODES OF OPERATION

The R/PA Software can, by means of command processing, be placed in any one of the following operational modes: OFF, STANDBY, LOAD, GROUND COMMANDED PROPAGATE (GCP), ALMANAC COLLECT, SPACE, RECEIVER TEST MODE (RTM), GROUND and CALIBRATE (CAL). The features of each mode of operation are summarized as follows:

1. OFF Mode. No power to the R/PA. Any program or data in the 56K word RAM memory is lost.

2. STANDBY Mode. Power is supplied to the oscillator, preamp, and the memory. When entered from the OFF mode, STANDBY is used to warm the oscillator to its stable temperature in preparation for operation in a navigation mode. It will require up to two hours for the oscillator temperature to stabilize. When entered from the COMMAND mode, STANDBY serves as the mode wherein the program is maintained in memory, but power is conserved by removing power from the central processing unit (CPU), memory controllers, and interface modules. Power is supplied to the external oscillator, the UT clocks and the TCG, and if previously established, the TCG is maintained. Uploading Discrete Command P3 (Main Power On) causes the R/PA to transfer (jump) to the Load Mode, or to the Command Mode, if the Set was placed in Standby from the Command Mode.

3. LOAD MODE. The LOAD MODE is the mode used to load the R/PA software and the data base into the RAM memory. The loader program does not monitor the solid state latches set by the Discrete Commands. Only the Loader Commands and the discrete commands that operate relays are processed when the R/PA is in the LOAD Mode.

The R/PA, upon initial power-up, from Standby, jumps to the boot loader which loads the load program and starts execution in the LOAD Mode. If the CPU is powered, uploading the Discrete Pulse Command P4 will cause the program to jump to the boot loader. Uplinking the Data Command START execution (4E3) causes the R/PA software to start execution in the COMMAND Mode.

4. COMMAND MODE. The COMMAND MODE is used to initialize the R/PA software functions, and to set the receiver channels. The GPS Subsystem can be placed in the command mode from either the load mode or from any navigation mode. While in this mode, telemetry is not available except for Echo Buffer (Data File 0) and Memory Dump (Data File 2). Both receivers are powered off and the current navigation solution (state) is propagated forward in time. Uplink of the appropriate pulse command (P6) transfers the Set to a predetermined navigation mode. The R/PA can be returned to the command mode by uplinking the appropriate pulse command (P5).

5. ALMANAC COLLECT MODE. The ALMANAC COLLECT MODE is used to gather the NDS almanac data required to refresh the almanacs currently stored in the R/PA processor memory. Each NDS satellite stores almanacs for the complete constellation of NDS and the almanacs are part of the available NDS telemetry data blocks. When the GPS Subsystem locks onto an NDS signal and if the almanac refresh flag is set, the R/PA, under software control, transfers to the ALMANAC COLLECT MODE. Upon a successful almanac refresh, the R/PA automatically exits to the originating navigation mode. The almanac collect mode can only be entered from a navigation mode. Telemetry is available and the current navigation state is propagated forward in time.

6. GROUND COMMANDED PROPAGATE Mode (GCP). Both receiver channels are off. The Set propagates its current navigation state estimate every six seconds. This mode is entered only from the COMMAND mode and exists back to that mode. Telemetry output data will be available during this mode.

7. SPACE Mode. This is the normal mode of operation of the R/PA for navigating in a space environment. When one or more satellites are in view, the NDS selection function selects a satellite and the receiver processing function measures the pseudorange and the delta pseudorange. The navigation filter inputs these measurements and updates the navigation state of the spacecraft. If no satellites are in view or if the receiver fails to track an NDS, the previous navigation state is propagated forward in time. The SPACE mode is entered only from the COMMAND or ALMANAC COLLECT modes and exists only back to those modes. Telemetry output will be available. Depending upon the commanded receiver configuration, operation in a single channel sequential 4, or dual channel simultaneous 4, satellite sequencing pattern will be performed as shown in Figure 15.3.1-1. If both receiver channels are commanded off, the current navigation solution is propagated forward in time. The submodes that use the receiver are described in greater detail as follows:

   a. Single channel sequential 4. The R/PA uses the receiver channel declared as primary by command to sequence over up to four Navigation Development Satellites. The secondary channel is off. Six seconds is spent on each satellite. During the first 2 seconds, pseudorange and delta pseudorange measurements are made on L1; during the next 3 seconds the same measurements are made on L2. Ionospheric corrections are computed from the sequential measurements an appropriate compensations introduced.

   b. Dual channel simultaneous 4. The R/PA uses both receiver channels to make simultaneous measurements to the same satellite. The primary channel makes pseudorange and delta pseudorange measurements on the L1 frequency, and the secondary channel makes pseudorange and delta-pseudorange measurements on L2 fraequency for the same satellite being tracked on the primary channel. The measurements made on the two channels are for the same 20 msec epoch detected on each channel to obtain "simultaneous" L1 and L2 measurements. Ionospheric corrections are computed using the simultaneous L1 and L2 measurements and are used to compensate the primary channel measurement information supplied to the navigation function.

```
          Sat 1    Sat 2    Sat 3    Sat 4    Sat 1    Sat 2
P         L1 L2    L1 L2    L1 L2    L1 L2    L1 L2    L1 L2
 +----------------------------------------------------------------------+
S          OFF      OFF      OFF      OFF      OFF      OFF
 +----------------------------------------------------------------------+
          6sec.    6sec.    6sec.    6sec.    6sec.    6sec
```

Single Channel Sequential 4

P = Primary Channel
S = Secondary Channel

```
          Sat 1    Sat 2    Sat 3    Sat 4    Sat 1    Sat 2
P         L1  *    L1  *    L1  *    L1 |*    L1  *    L1  *
 +-----------------------------------------------------+
S         L2  *    L2  *    L2  *    L2  *    L2  *    L2  *
 +-----------------------------------------------------+
          6sec.    6sec.    6sec.    6sec.    6sec.    6sec.
```

Dual Channel Simultaneous 4

*Idle

Figure 15.1-6. Sequential Track Receiver Sequences

8. RECEIVER TEST MODE (RTM). In this mode, the receiver channels track the same NDS signal which provides a means for evaluating the proper receiver operation. Telemetry is available in this mode. RTM can be entered only form the Command Mode. The RTM requires ground navigation and is not intended for use in a space environment but only for testing on the ground.

9. GROUND Mode. This is the mode of operation of the R/PA for navigating in a ground environment (i.e., on or near the Earth's surface). Except for differences in the navigation and satellite selection functions inherent in the different host vehicle environment, this mode provides identical capabilities as those described for the SPACE mode. The GROUND mode is entered only from the COMMAND mode and exists only back to that mode.

10. CALIBRATE (CAL) Mode. The GPS Subsystem Software is used to calibrate the R/PA oscillator for frequency and phase bias. The calibration method used requires that the Set be stationary and that ground

navigation be performed. This mode is identical to the GROUND Mode, except that the Kalman filter implementation forces the velocity component of the state to be zero. Telemetry output will be provided during this mode. The CAL mode is entered only from the COMMAND mode and exists only back to that mode.

15.3.1 GPS SUBSYSTEM MONITOR

The GPS Subsystem monitor function controls the transition between the various system states. The monitor performs the following:

1. Initialization processing which controls the initialization of the satellite selection function, the navigation function and the receiver processing function. All must be initialized before the Set can make the transition to the selected navigation state (mode) of operation.

2. Navigation processing which controls the functions required to perform the navigation state.

3. Pulse/GPS Subsystem interface to control transitions from a navigation mode to the Command Mode operation.

4. GPS Subsystem/Critical Telemetry Interface which reports on the current status of the GPS Subsystem.

15.3.2 INITIALIZATION PROCESSING

Anytime the Set processes a command to transfer to any navigation mode (SPACE, GCP, RTM or CAL), the System Monitor calls the initialization processor. The initialization processor will perform either a "cold start" or a "restart". A cold start sets a flag that no NDS has been acquired and that the Landsat-D almanac and NDS almanacs are to be used to acquire the first NDS. A restart indicates that one or more NDS's have been acquired and that only the NDS Selection Processor is to be initialized. A cold start is required if the last previous navigation mode was neither the SPACE mode or the GCP mode or if the GPS subsystem is up from either STANDBY or LOAD mode. Otherwise, a restart is required. (When the GPS transfers from the SPACE Mode to the COMMAND Mode, the current navigation state is propagated forward in time.)

The software determines which functions require initialization and automatically follows the procedure required to initialize these functions prior to making the transition to the selected navigation mode. The software function shown in Figure 15.3-2 determines if a cold start is required, and if so, sets the cold start flag. The software function shown in Figure 15.3-3 checks to determine if the cold start flag is set and if so, peforms the cold start functions necessary before entering the (Ground Commanded Propagate) GCP Mode. The software function shown in Figure 15.3-4 performs the initialization functions necessary before entering the SPACE Mode. It checks the health of the almanac data stored in memory, decides if a cold start is needed and if so, peforms the initialization functions required prior to entering the SPACE Mode. The software function checks to determine if an almanac collect is needed. If an almanac collect is not required, the cold start complete flag is set; otherwise the almanac collect required flag is set.

Upon completion of the initialization functions, the monitor transfers control to the scheduled navigation mode, and the final initialization may be completed after the transition to the specified navigation mode.

15.3.2.1 Space Mode Processor

After the receiver has made four successful NDS P-code acquisition attempts to lock onto the first NDS, the system monitor indicates that a "first fix" has been achieved and this signals that the Set was correctly initialized for operation in the SPACE Mode. Figure 15.3-5 shows the flow diagram of the Space State Controller Program.

15.3.2.2 GCP Mode Processor

GROUND COMMANDED PROPAGATE state turns off both receivers and, based upon previous data, the Set propagates the current navigation state.

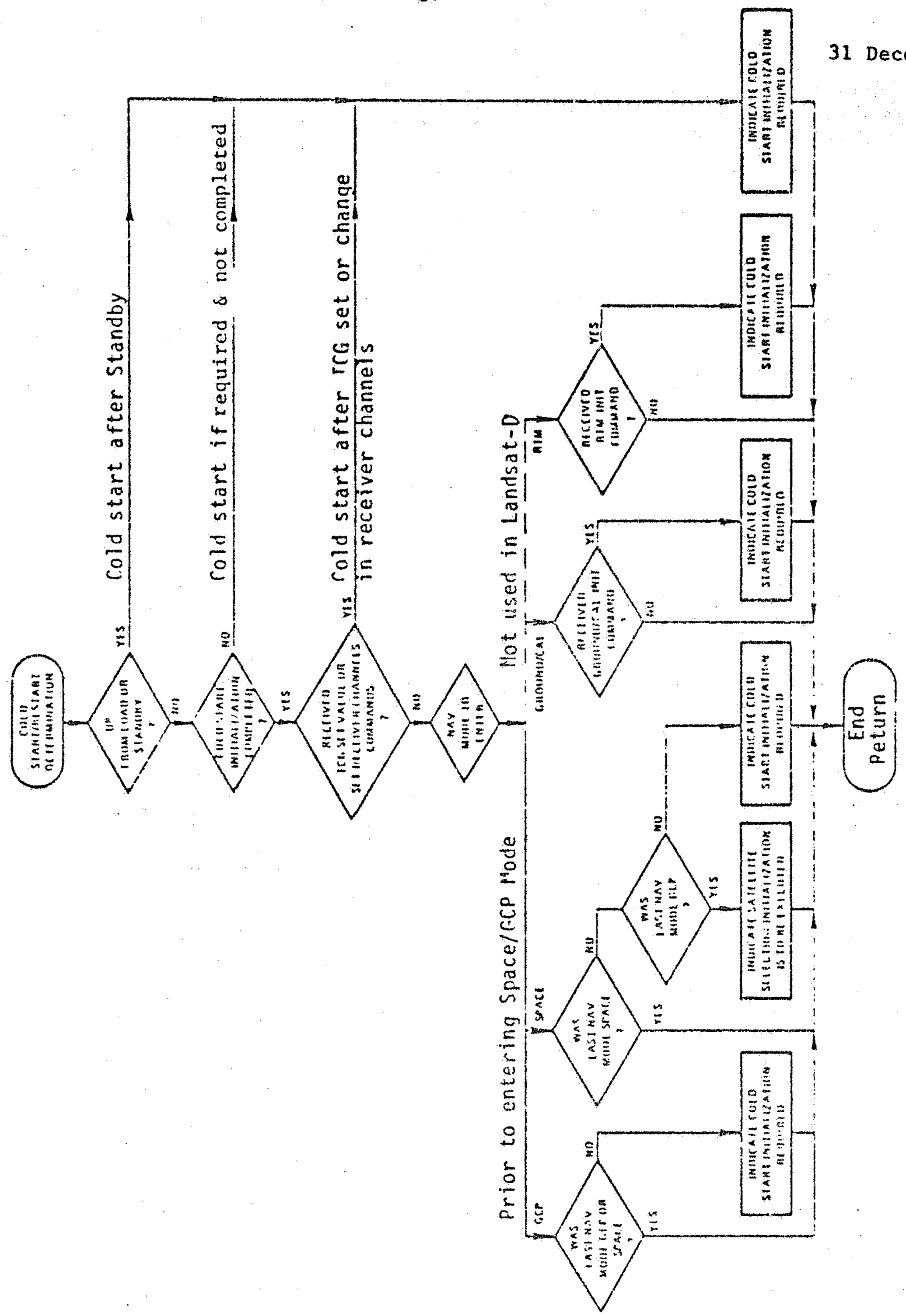

Figure 15.3-2. Cold Start/Restart Determination

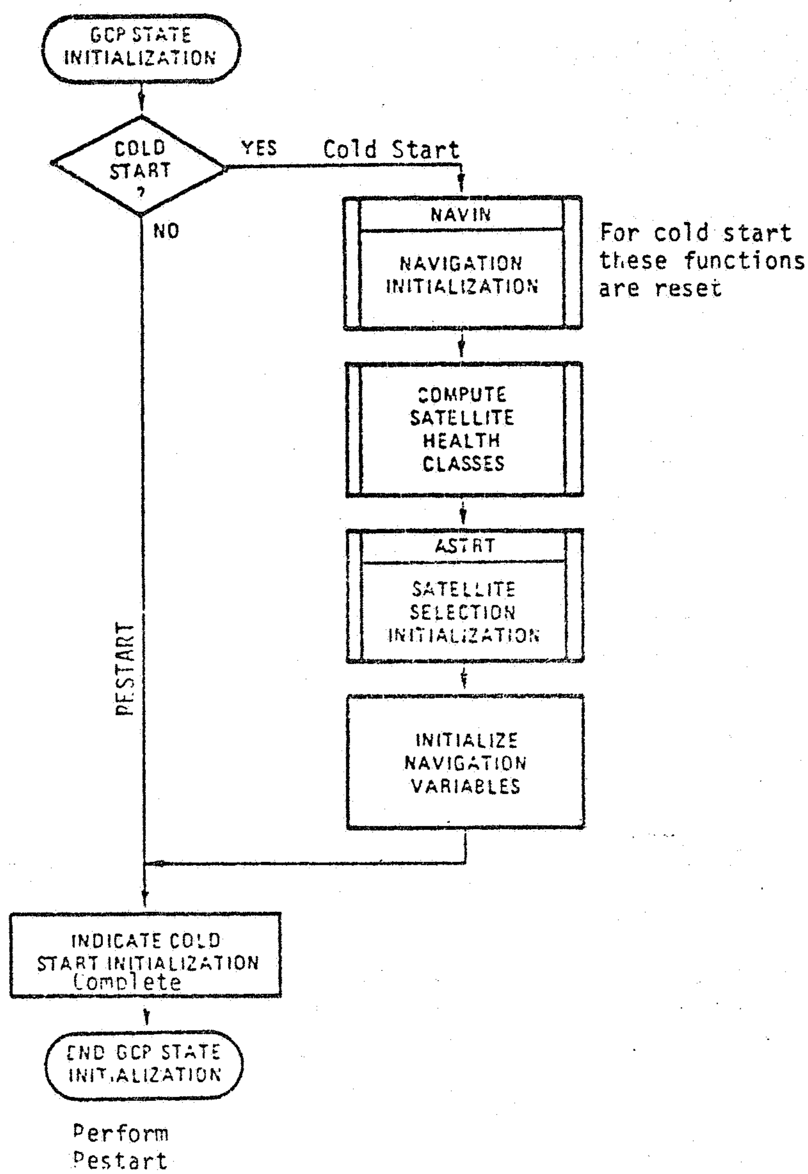

Figure 15.3-3. GCP Start Initialization

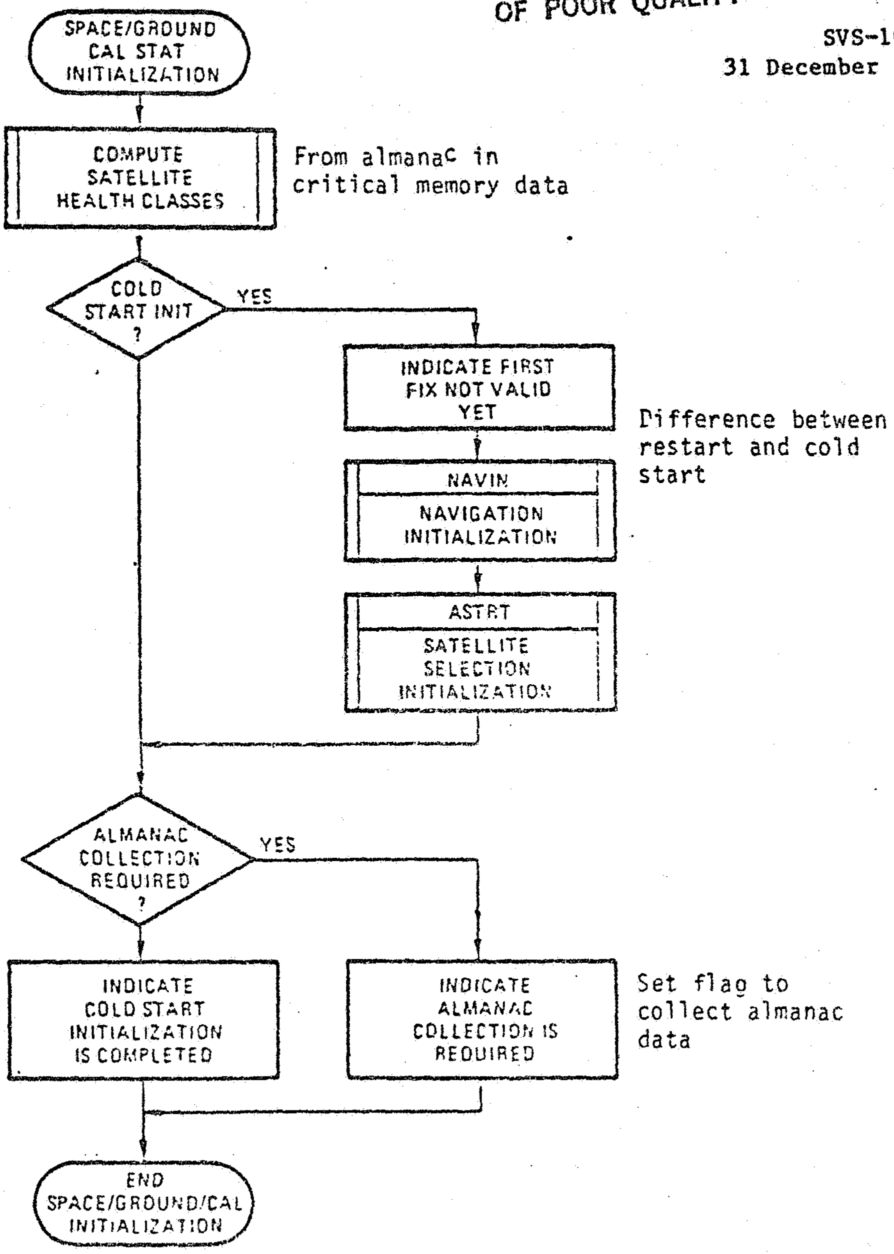

Figure 15.3-4. Space/Ground/Cal State Initialization Flow Diagram

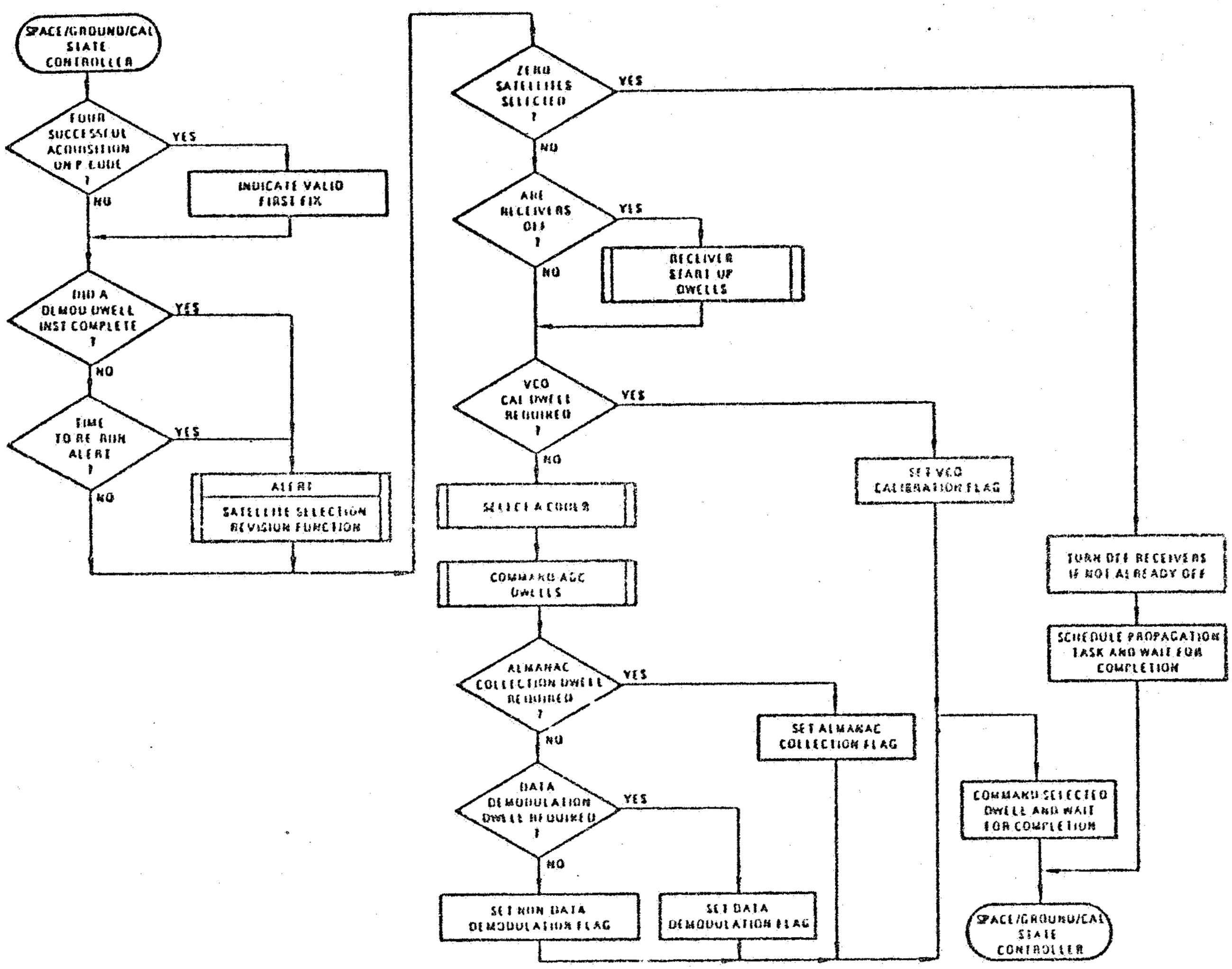

Figure 15.3-5. Space/Ground/Cal State Controller Flow Diagram

15.3.2.3 Almanac Collect Mode Processor

The R/PA processor requires an almanac for both the Spacecraft and the Navigation Development Satellite before it can acquire the NDS signal. The Landsat-D Almanac is uploaded by R/PA Data Command type 5 and the NDS Almanacs are initially uploaded by R/PA Data Command type 6. Each NDS transmits an almanac for all Navigation Development Satellites, and the NDS almanac can be obtained by demodulating the signal from the NDS currently being tracked.

15.3.2.4 Sequential Track State Processor

Each NDS continuously transmits information on both the L1 and L2 carrier frequencies. The sequential track state processes the two carriers sequentially. In this state the monitor controls the fixed dwell times used for the reception of NDS signals; provides regular telemetry using the telemetry processing function; the BIT background self test loop regularly checks system health; and the monitor regularly invokes the satellite selection function which maintains up to four NDS satellites that are to be used concurrently by the navigation function.

Navigation state: When the GPS Subsystem is tracking the required minimum number of satellites, the receiver measures the pseudorange and the delta pseudorange. The navigation function reads the available measurements and updates the navigation state.

15.4 CONSTRAINTS GPS-SUBSYSTEM

1. The GPS-Subsystem has only one Reference Oscillator instead of the two called for in the literature. The Discrete Pulse Command P8 (0805) Select Oscillator #2 should not be used since the Oscillator #2 is not included in the LANDSAT-D or LANDSAT-D Prime GPS Subsystem.

2. The Loader Command (4E1) MEMORY LOAD is the R/PA Data Command used to upload the R/PA memory contents. The number of 16-bit words uploaded by a single command should be limited to 64 words and the 6 least significant bits of the start address should be all zeros. This insures that the Loader Command (4E2) BIT MAP OUTPUT will produce the correct bit map.

3. The Loader Command (4E6) MEMORY DIAGNOSTIC is the R/PA Data Command used in the LOAD MODE to test the memory hardware. This test performs a write/read test on each word of RAM memory. The original content of the memory is lost and must be reloaded after each use of the Data Command.

4. The GPS Subsystem is powered up by first entering the STANDBY Mode. The main power ON is switched by relay from the standby power supply and the Discrete Pulse Command P1 (0861) must be uplinked to insure

that the main power relay contacts are open before the Discrete Pulse Command P2 (0834) is uploaded to place the GPS Subsystem on STANDBY power. See Paragraph 15.6.2 for details on power-up.

5. There is no Discrete Pulse Command which causes the GPS-Subsystem to enter the STANDBY MODE from any mode (except OFF). The Set can be placed on standby as follows: 1) Upload the Discrete Pulse Command P5 (0816) which will place the Set in the COMMAND MODE, 2) Upload the Operational Command SET Mode (1E2) with L flag set to zero. This causes the set to make the transition to STANDBY power from the COMMAND Mode.

6. The following timing constraints shall be followed during R/PA commanding:

   a. There shall be a delay of 1 second minimum between successive serial data commands. Certain serial commands, listed below, require a delay greater than 1 second.

      - A Memory Diagnostic command must be followed by a delay of at least 60 seconds.

      - A Command Mode command must be followed by a delay of at least 30 seconds.

      - There shall be at least a one second delay between R/PA Standby Power ON and R/PA OFF, between R/PA Main Power ON and R/PA OFF, and between R/PA OFF and R/PA Standby Power ON.

      - There shall be a delay of at least one minute after the Execute command.

   b. Certain serial data commands consist of multiple 48 bit words (40 bit R/PA commands). There shall be a delay of at least 6 milliseconds between each 48 bit word of these commands.

   c. Two OFF commands, separated by at least one second, are required to insure proper OFF state of the R/PA.

15.5 REDUNDANCY GPS-SUBSYSTEM

The GPS Subsystem provides essentially no redundancy. The On-Board Computer requires a navigation message for attitude control and for high gain antenna pointing angles. In the event these data are not available from the R/PA, the OBC must use the ground supplied ephemeris information needed for the critical operations. Also the daily update of the Spacecraft clock obtained from R/PA must be accomplished from ground controlled functions.

15.6 GPS COMMANDS

The GPS is controlled by commands to the R/PA (Receiver/Processor Assembly) only. There are no commands to the GPS Oscillator or to the GPS Preamp, which receive DC input power from the R/PA and are therefore controlled by the R/PA.

The R/PA responds to 16 discrete commands and to 16 serial commands. Two discrete commands to the PDU enable and disable the GPS input power.

15.6.1 DISCRETE COMMANDS

The discrete commands are given in Table 15.6-1. The commands SPRON (R/PA Standby Power ON), MPRON (Main Power ON), and MPROF (R/PA Power OFF) should each be followed by a one second delay before any other command is sent to the R/PA. In addition, the MPROF should be followed by a second MPROF (followed by a one second delay) to assure that a time delayed relay (K8 in Figure 15.6-1) has been reset.

The command CMMD (Command Mode) should always be followed by a one minute delay before any additional commands are sent to the R/PA. This allows the processor to finish its current task and return to the Command Mode.

15.6.2 SERIAL COMMANDS

Serial commands must be addressed to the R/PA only when the R/PA is in the proper mode for receiving commands. Six of the serial commands shall be sent to the R/PA only when the R/PA is in the Load Mode. The remaining 10 serial commands shall be sent to the R/PA only while it is in the Command Mode.

The division of the serial commands is as follows:

In Load Mode Only

1. Memory Load
2. Bit Map Output
3. Start Execution
4. Power Down (Go to standby)
5. Memory Dump
6. Memory Diagnostic

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Table 15.6-1. Discrete Commands

RIU	Chan	Acronym	Command Name
8	34	SPRON	R/PA Standby Power ON
8	20	MPRON	Main Power ON
8	61	MPROF	R/PA Power OFF
8	44	OS1	Select Oscillator 1
8	08	OS2	Select Oscillator 2
8	55	LDMD	Transfer to Load Mode
8	16	CMMD	Command Mode
8	46	NVMD	Navigate Mode
7	03	TCST	TCG Set Mode
7	47	TCRN	TCG Run Mode
7	15	TMØ	Time Mark T-Ø
7	25	TM1	Time Mark T-1
7	45	TM2	Time Mark T-2
7	61	TM3	Time Mark T-3
7	29	TMOD	Select Telemetry Mode Serial Output
7	19	CMOD	Select Computer Mode Serial Output
6	02	ENAGPS*	GPS Power Enable
6	37	DISGPS*	GPS Power Disable

*The last two commands are effected in the Power Distribution Unit (PDU).

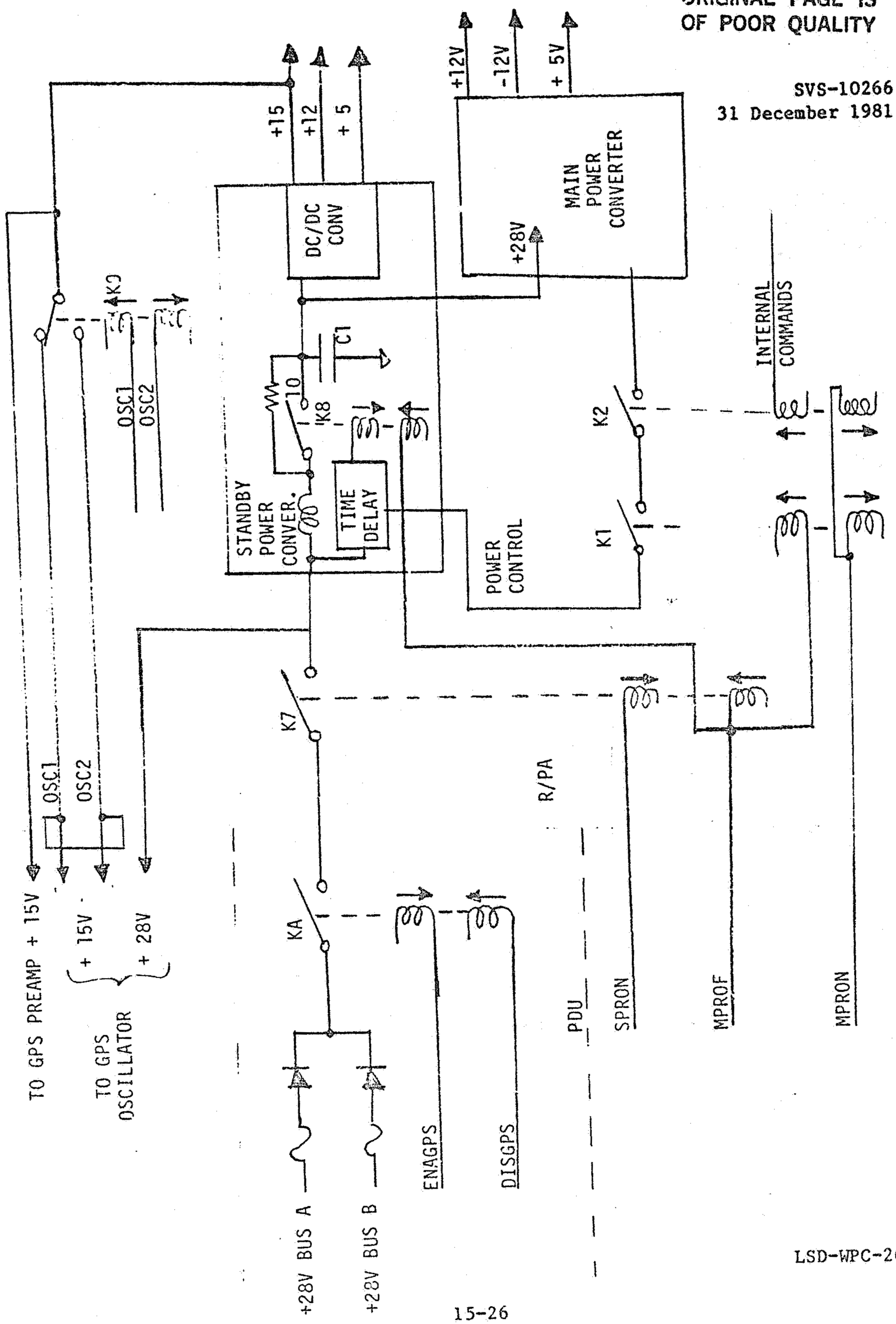

Figure 15.6-1. DC Power Input Control Command Interface

LSD-WPC-263

In Command Mode Only

1. Set Receiver Channel
2. Set Mode
3. Set Data File Index
4. TCG Set Value
5. HV Almanac Upload
6. NDS Almanac Upload
7. Ground/Cal Initialization
8. RTM Initialization
9. Memory Dump
10. Echo Data Command Buffer

The serial command bit structure and details are given in Appendix A.

GPS serial commands consist of 48 bits, or multiples of 48 bits. The first eight bits of each 48 bits are ignored by the R/PA.

Three ground commands are required to transfer 48 bits to the R/PA. The first two ground commands are addressed to RIU 7, Channel 71. The third ground command must be addressed to RIU 7, Channel 72.

The length of a complete serial command is determined by its type. Each complete command consists of a line or multiple lines where a line is defined as 48 bits (three ground commands), the first eight bits of which are ignored by the R/PA. The remaining 40 bits (5 bytes) are decoded by the R/PA. In those 5 bytes, the first byte identifies the line as part (or all) of a particular command and is unique to that command.

Individual lines of a command must not be sent at a rate faster than one line per six milliseconds. Successive serial commands shall be sent at a rate not faster than one per second.

The overall structure of the serial commands is given in Table 15.6-2, which shows the command name, the first byte of each line, and the number of lines contained in each serial command.

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Table 15.6-2. Serial Commands

Command Name	First Byte Structure 1	2	3	4	5	6	7	8	Number Of Lines	Total Lines
IN LOAD MODE										
Memory Load	1	0	0	0	0	0	0	1	1	
	0	0	0	0	0	0	0	1	1 to 32	
	0	1	1	0	0	0	0	1	1	3 to 34
Bit Map	1	0	0	0	0	0	1	0	1	1
Start Execution	1	0	0	0	0	0	1	1	1	1
Power Down	1	0	0	0	0	1	0	0	1	1
Memory Dump	1	0	0	0	0	1	0	1	1	1
Memory Diagnostic	1	0	0	0	0	1	1	0	1	1
IN COMMAND MODE				*						
Set Receiver Channels	0	0	1	E	0	0	0	1	1	1
Set Mode	0	0	1	E	0	0	1	0	1	1
Set Data File	0	0	1	E	0	0	1	1	1	1
TCG Set Value	0	1	0	E	0	1	0	0	1	
	0	1	1	0	0	1	0	0	1	2
HV Almanac Load	0	1	0	E	0	1	0	1	1	
	0	0	0	0	0	1	0	1	4	
	0	1	1	0	0	1	0	1	1	6
NDS Almanac Load	0	1	0	E	0	1	1	0	1	
	0	0	0	0	0	1	1	0	5	
	0	1	1	0	0	1	1	0	1	7
Ground/Cal Initialization	0	1	0	E	0	1	1	1	1	
	0	0	0	0	0	1	1	1	5	
	0	1	1	0	0	1	1	1	1	7
RTM Initialization	0	1	0	E	1	0	0	0	1	
	0	0	0	0	1	0	0	0	6	
	0	1	1	0	1	0	0	0	1	8
Memory Dump	0	1	0	E	1	0	0	1	1	
	0	1	1	0	1	0	0	1	1	2
Echo Data Command Buffer	0	0	1	E	1	0	1	0	1	1

*The bit designated "E" is the Echo Bit. If E is a logical 1, the entire command will be placed in the Echo Buffer, to be read out later. In the Load Mode commands, the Echo Bit is not allowed; it must be logical 0.

In the Load Mode commands, the first three bits of the first byte of each line are as follows:

100 if is the first line
000 if it is an intermediate line
011 if it is the last line

The fourth bit is always a logical zero. The last four bits indicate the sequential number of the command.

In the Command Mode commands, the first three bits of the first byte are as follows:

001 if it is the first line of a one-line command
010 if it is the first line of a command having more than one line
000 if it is an intermediate line
011 if it is the last line

The fourth bit is the Echo Bit (E) if it is the first line, and is logical zero otherwise.

The last four bits indicate the sequential number of the command.

The syntax of the commands given above is important in that if the syntax is violated, the command will be rejected. If the R/PA is in the Command Mode at the time of the error, an appropriate error message will be placed in the Echo Buffer, followed by the failed command, regardless of the state of the Echo Bit.

15.6.3 COMMAND SEQUENCES

If the GPS is OFF, the following sequence is recommended to put the GPS into an operating mode. (See 16.6.6 GPS constraints for delays and additional commands, which are deleted here for sequence clarity.)

1. Standby Power ON - Power is applied to the R/PA, oscillator and preamplifier.

2. Main Power ON - R/PA initializes and goes to Load Mode.

3. Memory Diagnostic * - Verifies integrity of memory. Optional. Destroys any previous memory load.

4. Telemetry Mode - To establish the Landsat data file format.

5. Bit Map - To evaluate the results of the memory diagnostic.

6. Load Mode - To reset the bit map to all zeros after the memory diagnostic.

7. Bit Map - To assure that bit map is set to all zeros.

8. Memory Load * - To supply the operating navigation program.

9. Bit Map - To establish integrity of load, as received by R/PA.

10. Memory Dump * - Optional. To have a record of each word loaded, as received by the R/PA).

11. Execute * - Starts execution of the Program loaded.

* Memory Diagnostic requires 30 seconds. Memory Load and Memory Dump time each depends on the extent of the load or dump. Execute requires one minute for initialization and transfer to the command mode.

Following the above sequence, the GPS is in the Command Mode, with memory loaded. To go further to an operating (navigating or propagating) mode, the following sequence is typical:

1. Set Receiver Channels * - Configures receiver channels and hardware, and acquisition mode.

2. Set Mode - Sets the R/PA operating mode.

3. TCG Set, TCG Set Value, TCG Run - Sets the Time Code Generator and starts it running.

4. NDS Almanac - At least one is required; the remainder can be collected.

5. HV Almanac - Required for Navigation or Propagation.

6. Set Data File Index - Instructs the R/PA to output specific data files with a specific frequency.

7. Ground/Calibration Initialization *

8. Receiver Test Mode Initialization *

*The Set Receiver Channels command must be given to the R/PA prior to the TCG Set Value command. The Ground/Cal and RTM Initialization commands are required only for subsequent entry to their respective operational modes.

There is no required order to the commands other than TCG Set, TCG Set Value, and TCG Run must be given in that order and Set Receiver channels must be given prior to TCG Set Value.

The above sequences are those required to prepare the GPS to do what is desired. One can now (or at any point previously in the Command Mode portion) request an Echo Buffer Data File (Data File #0) by issuing the serial command.

1. Echo Data Command Buffer - Data File #0 is output, containing all previous serial commands with E=1, plus all rejected commands with error message preceding each.

After verifying the commands and correcting those rejected (if any), one proceeds to start the Navigation:

1. Navigation Mode - The GPS now begins to perform the Navigation or Propagation that was commanded previously.

Navigation then starts with a Baseband Test (approximately three minutes), after which a Data File #11 (Receiver Diagnostic Data) is output if Data File #11 was requested.

One can conclude the Navigation by command:

1. Command Mode - Should be followed by 60 second delay prior to additional commanding.

The R/PA is now ready to receive serial commands to (1) issue preparatory commands for a new mode of operation, or (2) go to standby by use of the Set Mode command.

Table 15.6-3 lists the commands which must be uplinked (after a memory load or a return from standby) before transition to a navigate mode will be allowed. The commands marked with an "X" for a given navigate mode must be received by command processing prior to a transition to that mode.

Table 15.6-3. Required Commands for Navigate Mode Transitions After Load or Standby

	To Propagate Mode	To Space Mode	To RTM Mode	To Ground or Cal Modes
Set Receiver Channels	X	X	X	X
Set Mode	X*	X*	X*	X*
NDS Almanac Upload		X	X**	X
HV Almanac Upload	X	X		
Ground/Cal Init				X*
RTM Init			X*	
Set TCG Time	X	X	X	X

* Those commands which, on a return from Standby, must be received after the transition from Standby.

** The NDS Almanac uploaded must correspond to the NDS specified (parameter RTMSID) in the RTM Initialization Data Command Message.

In addition, the Ground/Cal Init Command must be received prior to each transition to Ground Mode if the last navigate mode was anything other than ground mode. Likewise, Ground/Cal Init command must be received prior to each transition to Cal Mode if the last navigate mode was anything other than Cal Mode. That is, if the set is in Ground Mode and a transition is made back to Command Mode (pulse is sent by HV), there are no required commands to return to Ground Mode; however, if the set is in Cal Mode and the transition is made to Command Mode, the Ground/Cal Init Command must be received again before a transition to Ground Mode will be allowed.

Likewise, the RTM Init Command must be received prior to each transition to RTM Mode if the last navigate mode was anything other than RTM Mode.

15.6.4 COMMAND VERIFICATION

Methods of command verification are given in Table 15.6-4 which lists commands by acronym, their prerequisite commands, complement commands, and a reference paragraph for command descriptions.

15.6.5 COMMAND DESCRIPTIONS

This section provides descriptions of the command functions using the command acronyms of Table 15.6-1 and the command names of Table 15.6-2.

Functional schematics are provided as an aid to understanding the command interface. Exact circuit details are defined by drawings elsewhere.

15.6.5.1

SPRON
MPRON
MPROF
ENAGPS
DISGPS
OS1
OS2

Power to the R/PA (+28 volts) is supplied through the ENAGPS/DISGPS relay KA in the PDU, shown on the left of Figure 15.6-1. The R/PA primary power control relays consist of relay K7 which supplies +28 volts to the Standby Power Converter and K1 and K2 in series which control a Power Control signal to the Main Power Converter.

The secondary voltages from the Standby Power Converter supply +15 volt power to the Oscillator and Preamp, and maintenance power to the R/PA memory. Relay K7 also supplies +28 volts to the Oscillator oven. Thus, after oscillator oven warm-up and R/PA memory load, the R/PA readiness to operate is preserved as long as Standby Power is maintained.

Table 15.6-4. Command Verification

COMMAND	REFERENCE PARAGRAPH	PREREQUISITE	COMPLEMENT	TELEMETRY VERIFICATION COL. ROW	TELEMETRY VERIFICATION BIT (0 to 7)	REMARKS
DISCRETE COMMANDS						
ENAGPS	15.6.5.1	---	DISGPS	33,86	0	Bit = 1
DISGPS	15.6.5.1	---	ENAGPS	33,86	0	Bit = 0
SPRON	15.6.5.1	ENAGPS	MPROF	99,39	1	Bit = 1
MPRON	15.6.5.1	SPRON	MPROF	99,39	2	Bit = 1
MPROF	15.6.5.1	---	MPRON	99,39	2	Bit = 0
OS1	15.6.5.1	SPRON	OS2	99,39	3	Bits 3&4 are always "1" when Standby Pwr is ON
OS2	15.6.5.1	SPRON	OS1	99,39	4	
LDMD	15.6.5.2	MPRON	Serial Commands Power Down, or Execute	99,130	0-3	Bits = 0010
CMMD	15.6.5.2	MPRON	NVMD	99,130	0-3	Bits = 0100
		Memory Loaded		99,39	5	Bit = 0
NVMD	15.6.5.2	Memory Loaded Proper Preparatory Commands	CMMD	99,130	0-3	Bits = 0011 (Propagate) or 0111 (Rec'r Test) or 0101 (Ground) or 0110 (Calibration) or 1XXX (Space)
				99,39	5	Bit = 1
TCST	15.6.5.3		TCRN	99,39	0	Bit = 0
TCRN	15.6.5.3		TCST	99,39	0	Bit = 1
TMØ TM1 TM2 TM3	15.6.5.4	GPS Navigating	---	---		Verification by Time Marks in Data File #7
TMOD	15.6.5.5	MPRON	CMOD	10,ALL	1	Bit = 0
CMOD		MPRON	TMOD	10,ALL	1	Bit = 1
SERIAL COMMANDS						
Memory Load	15.6.5.6	Load Mode	---	Verification by request of memory dump, or of Bit Map		Data File #2
Bit Map Output	15.6.5.7	Load Mode		Verification by Bit Map output		Data File #1 Data File #1

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Table 15.6-4. Command Verification (Continued)

COMMAND	REFERENCE PARAGRAPH	PREREQUISITE	COMPLEMENT	TELEMETRY VERIFICATION COL. ROW	TELEMETRY VERIFICATION BIT (0 to 7)	REMARKS
Start Execution	15.6.5.8	Load Mode	---	Subsequent R/PA transition to Command Mode 99,130	0-3	Bits = 0100
Power Down	15.6.5.9	Load Mode	---	R/PA returns to Standby 99,130	0-3	Bits = 0000
Memory Dump	15.6.5.10	Load Mode	---	Verification by output of memory dump		Data File #2
Memory Diagnostic	15.6.5.11	Load Mode	---	Verification by Bit Map with all data = 1		Data File #1
Set Rec'r Channels	15.6.5.12	Command Mode	---	All serial commands in Command Mode can be verified by setting the Echo Bit = 1 and commanding an Echo Buffer Data File Output		Data File #0
Set Mode	15.6.5.13	Command Mode	---			
Set Data File Index	15.6.5.14	Command Mode	---			
TCG Set Value	15.6.5.15	Command Mode	---			
HV Almanac Upload	15.6.5.16	Command Mode	---			
NDS Almanac Upload	15.6.5.17	Command Mode	---			
Ground/Cal Init.	15.6.5.18	Command Mode	---			
RTM Init.	15.6.5.19	Command Mode	---			
Memory Dump	15.6.5.20	Command Mode	---			
Echo Buffer	15.6.5.21	Command Mode	---			

The Main Power Converter supplies the power required for R/PA operation.

Relay K8 is open at initial turn-on so that the capacitors C1 are initially charged through a 10 ohm resistor. In less than a second after initial turn-ON, relay K8 is closed by the time delay circuit, shorting the 10 ohm resistor and enabling a power-control circuit to the Main Power Converter.

The MPRON (Main Power ON) command closes both K1 and K2 relays, applying prime power to the Main Power Converter. Main power can be turned OFF (K2 opened) by internal command only. MPROFF opens relays K1 (Main Power), K7 (Standby Power), and resets relay K8. Because of a sneak path, relay K8 may sometimes not open with the first MPROF and for this reason a second MPROF is recommended after a one second delay.

The selection of oscillator 1 or 2 is effected by K9, which applies +15 volt power to one of two lines going to the oscillator. The two lines are effectively joined, as shown by the spacecraft harness at the R/PA interface, supplying +15 volts to the oscillator through a pair of lines. The R/PA is used on another spacecraft, which has dual oscillators.

15.6.5.2

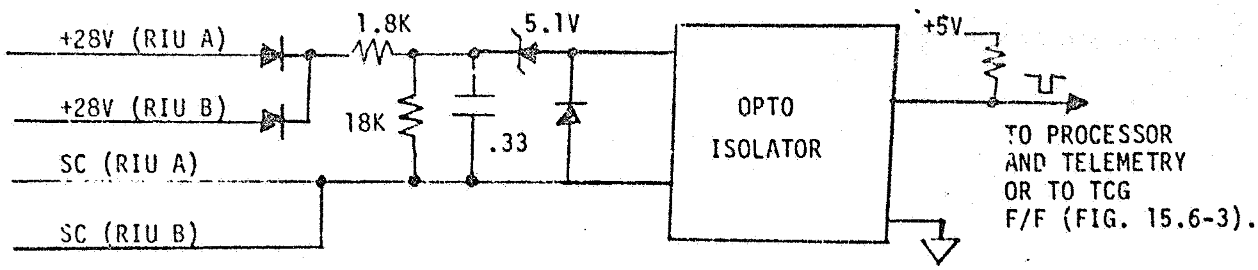
LDMD
CMMD
NVMD

These three commands are interfaced into the R/PA by opto-isolators, as shown in Figure 15.6-2. The LDMD opto-isolator output feeds directly into the R/PA processor, while the CMMD and NVMD outputs feed into opposite sides of a logic latch (flip/flop) whose output goes to the R/PA processor and to telemetry.

The CMMD signal to the processor in effect tells the processor to finish the current Navigation task and then switch to the Command Mode. A 60 second delay should follow CMMD before additional commands are issued.

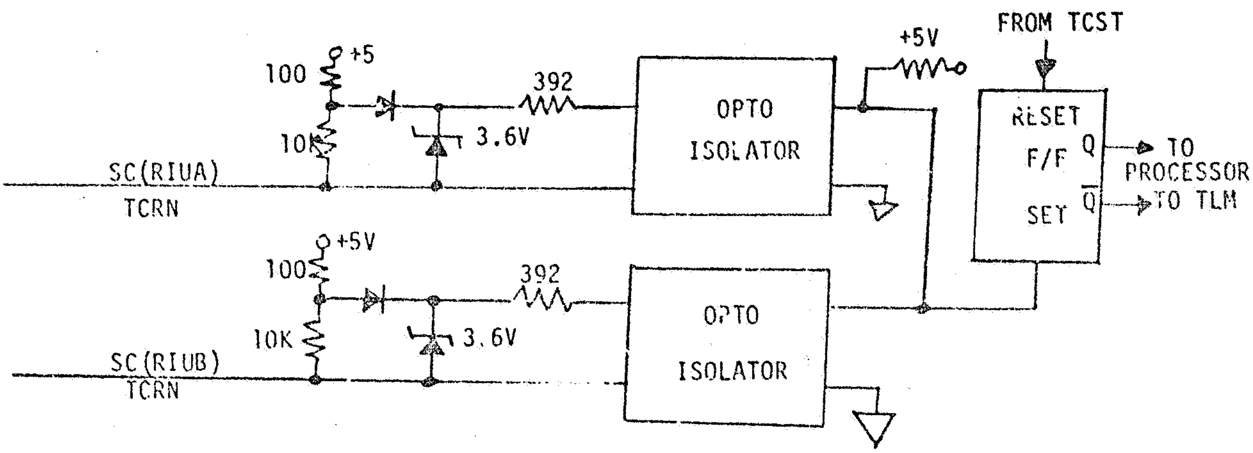
The LDMD command is used to force the processor to the Load Mode from the Command Mode. The LDMD command will also set the Bit Map to all zeros.

The NVMD command initiates navigation in the configuration and mode specified by preparatory serial commands given previously in the Command Mode. If the preparatory commands are inadequate for the navigation mode that was specified, the processor will not begin navigation, and will set the Invalid Transition telemetry flag. Also, an appropriate error message will be placed into the Echo Buffer.



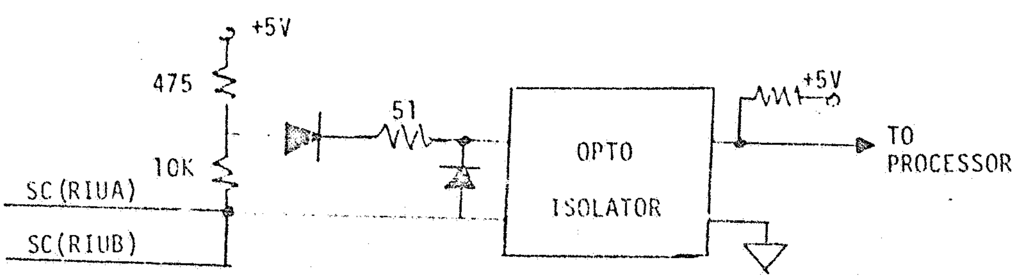
SC = Switch Closure to Signal Ground

Figure 15.6-2. Command Interface for LDMD, CMMD, NVMD, TCST



SC = Switch Closure to Signal Ground

Figure 15.6-3. Command Interface for TCRN



SC = Switch Closure to Signal Ground

Figure 15.6-4. Command Interface for T0, T1, T2, T3

15.6.5.3

TCST
TCRN

The TCST command prepares the Time Code Generator (TCG) to be set by inhibiting the clock pulses (1.023 MHz). See Figure 15.6-2 for the interface circuit, and Figure 15.6-3 for coupling with the TCRN command. After the TCST command is received, the TCG is ready to be set by the serial data command TCG Set Value (Paragraph 15.6.5.15).

Following the TCG Set Value command, receipt of the TCRN command by the R/PA removes the inhibiting of the clock pulses, and the TCG begins counting from the time set by the Set Value command. The TCRN interface is shown in Figure 15.6-3.

15.6.5.4

TMØ
TM1
TM2
TM3

Each of the Time Marks strobes the TCG and places the current TCG time into a time code buffer, and the time code buffer is entered into Data File #7 when Data File #7 is output. Each TCG time placed into the time code buffer is tagged with the number of the Time Mark that generated it. The command interface is shown in Figure 15.6-4.

15.6.5.5

TMOD
CMOD

The commands TMOD and CMOD determine whether the telemetry serial data shall be output by the R/PA in the Telemetry Mode or Computer Mode. Landsat always uses the Telemetry Mode in which:

1. The Data Ready signal is set to a logic "1" in synchronism with the Minor Frame Sync pulse.

2. Telemetry data files all have a uniform length - 944 bits (118 8-bit words).

3. There is at least ıe telemetry minor frame of all zeros following each data file tha' is output.

In the Computer Mode (not used by Landsat):

1. The Data Ready signal is set to a logic "1" in synchronism with the Word Rate signal.

2. Telemetry data files vary in length.

3. Successive data files may be contiguous; i.e., there is not necessarily a minor frame of all zeros between successive files as they are output.

The R/PA is set to the Computer Mode automatically when Standby Power is turned ON (SPRON), so it is necessary to send TMOD prior to the output of data files.

The command interface circuit is shown in Figure 15.6-5.

15.6.5.6 Memory Load

Memory Load is a serial data command. The command interface circuit for serial commands is given in Figure 15.6-6.

Memory Load is a variable length command that can range from three lines (blocks) to 34 lines, thus including a range of memory words from 1 to 64. The command requires that three parameters be specified.

1. A, the starting address of the load
2. N, the number of sequential 16-bit words to be loaded.
3. W, the 16 bits of each word.

The Memory Load command will be accepted by the R/PA only when the R/PA is in the Load Mode.

15.6.5.7 Bit Map Output

Bit Map Output is a serial data command. See Figure 15.6-6 for the electrical interface.

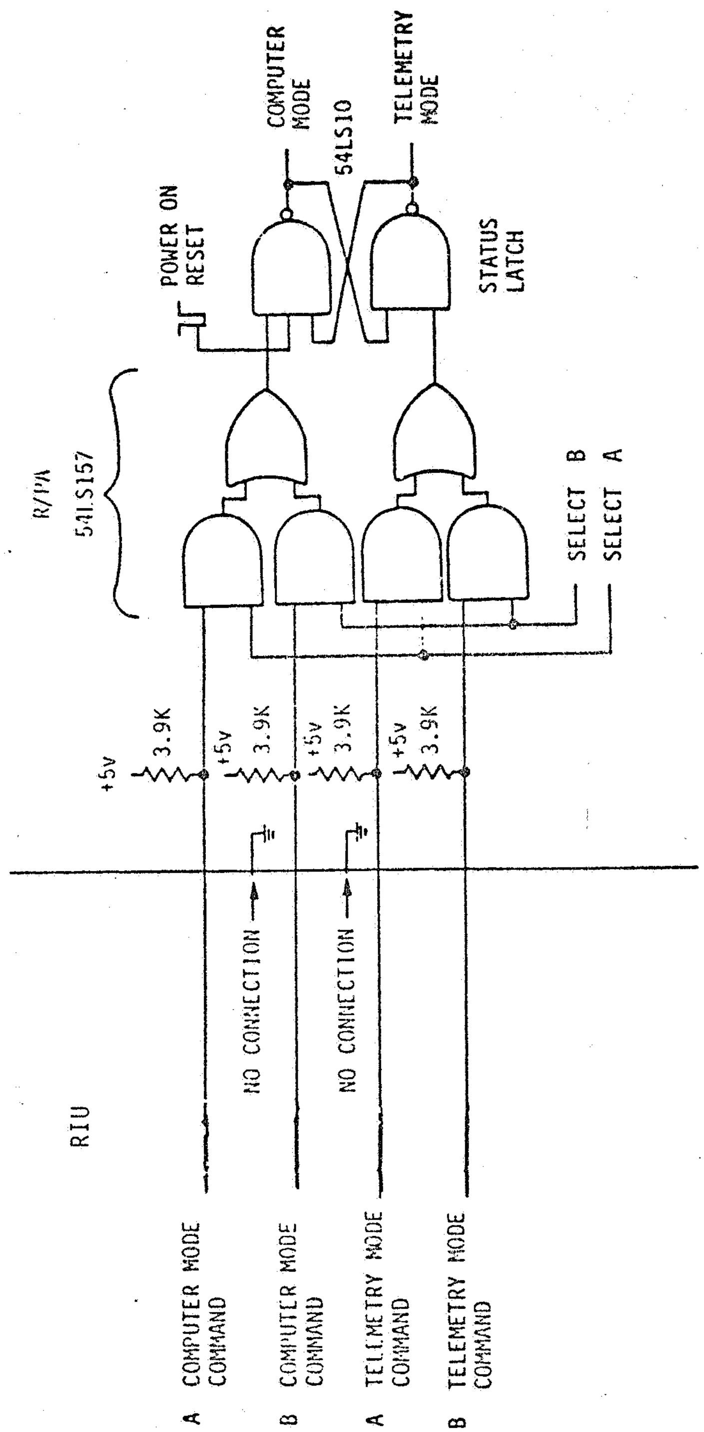


Figure 15.6-5. Computer/Telemetry Data Mode Command Interface for TMOD, CMOD

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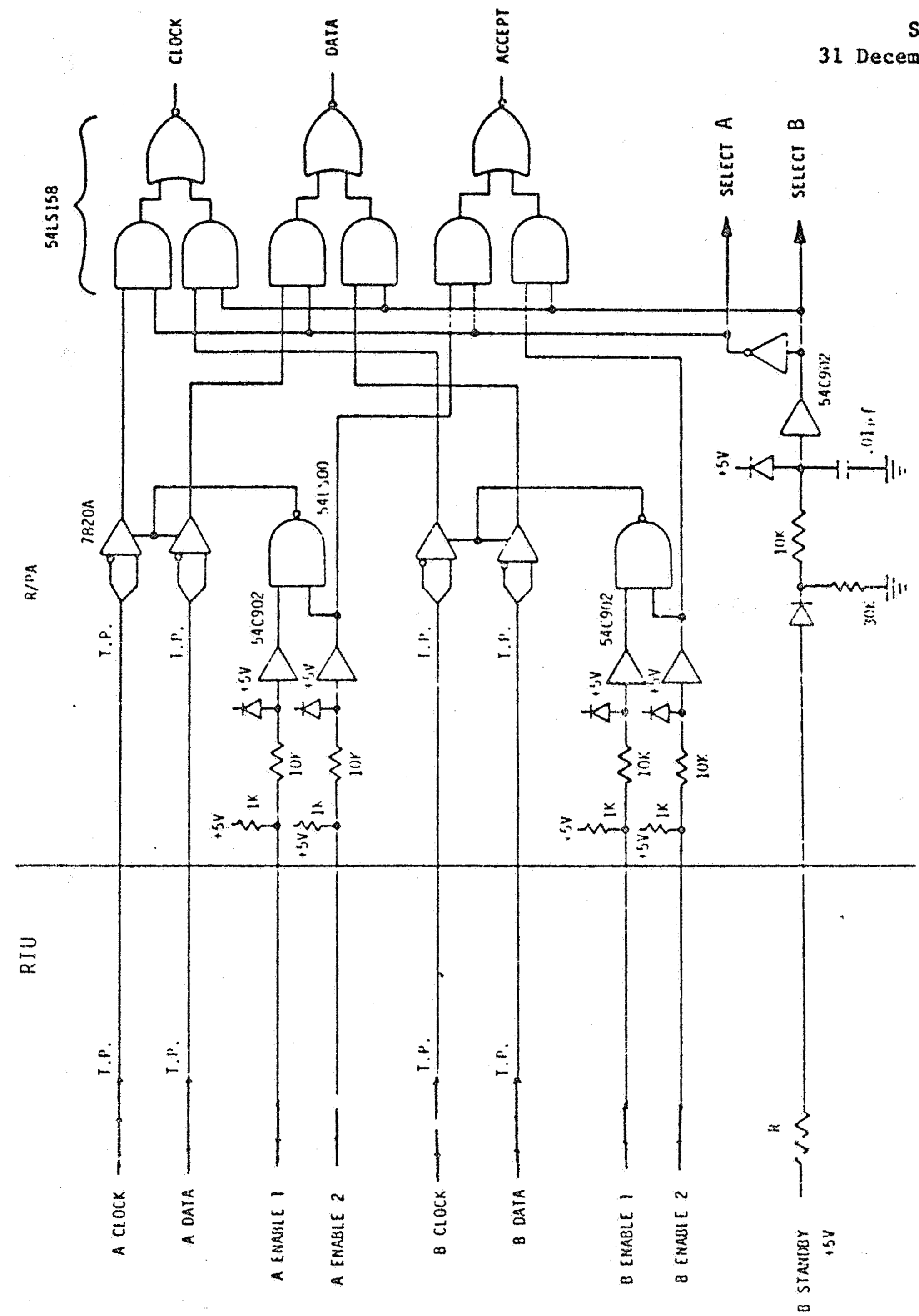

Figure 15.6-6. Serial Data Command Interface

The command requires the specification N, indicating how many times the Bit Map is to be transmitted.

The Bit Map (Data File #1) is a check of the accuracy of a memory load, as received by the R/PA. A logic 1 in the Bit Map indicates that the checksum transmitted with a Memory Load message containing 64 16-bit words agrees with a checksum performed by the R/PA on those 64 words. The starting address on each 64 words must be a multiple of 64.

The Bit Map is also used to verify a Memory Diagnostic Test.

The Bit Map Output is accepted by the R/PA only in the Load Mode.

15.6.5.8 Start Execution

The Start Execution command is a serial data command. See Figure 15.6-6 for the electrical interface.

After a complete Memory Load which has been verified by Bit Map and/or memory dump and verification thereof, operation of the program is initiated by the Start Execution command. The only parameter to be specified is the address at which execution is to begin. The execution shall be followed by a one minute delay to allow for initialization. At the end of the execution, the R/PA will be in the Command Mode.

Start Execution can be received in the Load Mode only, and only after a completed memory load.

15.6.5.9 Power Down

The Power Down command is a serial data command. See Figure 15.6-6 for the electrical interface.

The power Down command can be accepted only in the Load Mode, and is used primarily for partial memory loading. After a partial load, the Power Down Command allows a return to the Standby Mode. When the next partial load is to begin, the MPRON command will turn Main Power ON and the R/PA will be in the Load Mode.

The Power Down command may be used successively for multiple partial memory loads.

15.6.5.10 Memory Dump

The Memory Dump command is a serial data command. See Figure 15.6-6 for the electrical interface.

The Memory Dump command initiates a dump of the R/PA memory. The command is accepted only in the Load Mode.

The parameters that must be specified are (1) the number of 256 word blocks to be dumped and (2) the location where the dump is to begin. The parameters must be such that all of the memory locations requested are within the range of the R/PA memory; i.e., 0 to 57,343 inclusive (decimal notation). The dump will begin immediately after the command is received by the R/PA.

15.6.5.11 Memory Diagnostic

The Memory Diagnostic is a serial data command. See Figure 15.6-6 for the electrical interface.

The Memory Diagnostic command initiates a self-test routine in which each memory address is written to and then read out. The Read-Write values are compared. The diagnostic test requires 30 seconds, and a 30 second delay should follow the command to allow time for the test.

A Bit Map command should follow the Memory Diagnostic (after 30 seconds). Each logic 1 in the Bit Map indicates a correct write-read comparison of 64 addresses.

By the write-read procedure, the test destroys prior memory load, and should be used therefore before memory load.

15.6.5.12 Set Receiver Channels

Set Receiver Channels is a serial data command which must be received by the R/PA in the Command Mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command directs the specific configuration of the receivers A and B, the channel configuration, and the acquisition mode. Three parameters must be specified:

1. P, which specifies receivers off, single channel (primary ON only) or dual channel (both channels ON).

2. C, which specifies normal or crossed receiver channel configurations.

3. M, which specifies acquisition mode.

15.6.5.13 Set Mode

The Set Receiver Channels command must be sent before the TCG Set value command.

Set Mode is a serial data command which must be received by the R/PA in the Command Mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command directs the subsequent operational configuration of the R/PA. Three parameters must be specified:

1. L, which directs the R/PA to go to the Standby Mode immediately, or to prepare for a Navigation Mode. If L is a logic 0, software will turn OFF the main power converter by resetting K2, shown in Figure 15.6-1. If M is set to logic 0, the R/PA will return to the Command Mode when MPRON later turns the Main Power Converter ON.

2. M, which directs the R/PA to the Command Mode or to any of five Navigation Modes.

3. N, which directs the R/PA to a mode of NDS (Navigation Data Satellite) Almanac collection.

15.6.5.14 Set Data File Index

Set Data File Index is a serial data command which must be received by the R/PA in the Command Mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command directs the subsequent frequency of output of Data Files 3 through 11. Files 0 (Echo Buffer), 1 (Bit Map) and 2 (Memory Dump) are output by direct command requests only, and the Data File Index command cannot be used to request their outputs.

Two parameters must be specified:

1. F, which identifies the Data File being addressed. As noted above, only files 3 to 11 must be addressed.

2. TR, which indicates the periodicity of output desired for the file, in terms of the Navigation Cycle. The allowed range is from one approximately every six seconds to one approximately every 2.3 days. The value of TR is applicable to files 4, 7, 8 and 10 only. For files 3, 5, 9 and 11, the fact alone that TR is greater than zero indicates

only that the file shall be output when new data are available. Landsat will not use file 6.

If TR is equal to zero, the indicated file is not be output at all. If a Set Data File Index command for particular file is not transmitted, that file will not be output.

15.6.5.15 TCG Set Value

TCG (Time Code Generator) Set Value is a serial data command which must be received by the R/PA in the Command Mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command sets the TCG to a specific time, indicated by the command itself. Prior to giving the command, the TCG must be stopped by the discrete command TCST. After the TCG Set Value command is transmitted, the discrete command TCRN must be given so that the TCG will start running from the Set Value time. The TCRN command must be sent so as to start the TCG within two seconds of the Set Value of time, otherwise acquisition of NDS satellites will not be possible.

Two parameters are specified for setting time:

1. T, which specifies the time elapsed from some designated time T_0, such as the beginning of the year. T then becomes TCG time when the TCG is started by TCRN.

2. D, which specifies the offset between (A) the last time before T_0 when GPS time = 0 and (BO T_0. Alternately defined, it can be stated that D = GPS time at T_0. GPS time is defined as the time elapsed since 2400^h Saturday*; GPS time is effectively reset to zero at 2400^h (GMT) every Saturday*.

A third parameter, M, is included in the TCG Set Value command. M is not related to any time code, but provides a means of masking (inhibiting) time marks TM0, TM1, TM2, and TM3. The TCG Set Value can be used to alter the mask values without prior use of TCST.

The value of M will be stored and used to control the masking of the Time Marks.

*GPS time, as transmitted by the NDS satellites, is not adjusted for Leap Seconds. GPS time, as of December 1981, has been running long enough to have accumulated three leap seconds. As a result, GPS time equals three seconds at 2400^h GMT Saturday, i.e., GPS time is reset to zero at three seconds before 2400^h GMT each Saturday.

15.6.5.16 Host Vehicle Almanac Upload

The Host Vehicle (HV) Almanac Upload is a serial data command which must be received by the R/PA in the Command Mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command specifies the Landsat orbit in Keplerian orbit parameters.

A Landsat Almanac must be specified for all Navigation modes except Receiver Test Mode, Ground Mode and Calibration Mode.

15.6.5.17 NDS Almanac Upload

The NDS Almanac Upload is a serial data command which must be received by the R/PA in the Command Mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command specifies the NDS Almanac (one for each NDS) in Keplerian orbit parameters.

The NDS Almanac for Space mode Navigation will be provided in hexadecimal data format to be commande directly.

NDS Almanacs are required for all modes of Navigation except Ground Commanded Propagation.

NDS Almanacs can be collected by the almanac collect feature (see Set Mode command), however, one initial NDS Almanac is always required for initial acquisition.

15.6.5.18 Ground/Calibration Initialization

Ground/Calibration Initialization command is a serial data command which must be received by the R/PA in the command mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command specifies initialization parameters for the ground or calibration mode.

15.6.5.19 RTM (Receiver Test Mode) Initialization

The RTM Initialization command is a serial data command which must be received by the R/PA in the Command mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command specifies initialization parameters for the Receiver Test Mode.

The command contains eight lines (blocks) and therefore requires 24 ground commands.

Nine initialization parameters must be specified:

(In the following, PR means pseudorange)

1. Initial PR estimate
2. PR rate
3. PR acceleration
4. Initial PR uncertainty
5. Subsequent PR uncertainty
6. Initial PR rate uncertainty
7. Subsequent PR rate uncertainty
8. Satellite ID
9. Prepositioning control

15.6.5.20 Memory Dump

The Memory Dump command is a serial data command which must be received by the R/PA in the Command mode only.

See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command requests a specific number of 16 bit R/PA memory words to be dumped, and the address at which the dump is to begin. The resulting output is Data File 2, R/PA memory contents.

Two parameters must be specified:

1. A, the address at which the dump is to start.

2. N, the number of 16 bit memory words to be dumped.

The request for a dump must contain parameters that request only addresses entirely within the R/PA range of addresses, namely, 0 to 57,343 (decimal). Thus, the limitations on A and N are (in decimal notation).

$$0 \leq A \leq 57,343$$
$$0 \leq A + (N-1) \leq 57,343$$

Memory locations 32,640 through 32,767 are non-addressable, and will appear as all zeros in the output when dumped.

The dump will begin immediately after the command is received.

15.6.5.21 Echo Data Command Buffer

This command is a serial data command which must be received by the R/PA in the Command mode only. See Figure 15.6-6 for the electrical interface.

If the E bit (4th bit of command) is a logic 1, the command will be stored in the Echo Buffer.

The command requests Data File 0 which contains a copy of all previous commands (whose E bit was a logic 1) plus all commands that contained errors (regardless of the E bit in those commands) and an error message preceding the erroneous command.

The error message preceding the erroneous command describes the command fault, such as checksum error, invalid command construction (too many or too few lines, trailer line out of sequence, etc.), invalid data (parameters out of range), or insufficient data for transition to the navigation mode requested.

Successive frames, each containing 22 lines (blocks), are output until the Echo Buffer is empty. Each frame contains 22 lines (blocks) of commands and/or error messages. Zeros fill unused lines. An EOT indicator (16 logic ones) indicates last frame.

All serial data commands transmitted in the Command Mode can thus be verified prior to commanding the Navigation mode.

The Echo Data Command Buffer command has no variable parameters; i.e., it is a fixed-field command.

The Echo Buffer is set to all zeros after the Data File has been transmitted.

15.6.6 GPS CONSTRAINTS

1. The R/PA can be damaged if voltage is brought up slowly from 0 volts to +28 volts (in greater than 10 milliseconds). Therefore, voltage is to be applied to the R/PA only by a switch closure to the fully energized power bus.

2. The R/PA shall be verified OFF prior to de-energizing the FS.

3. Single lines (48 bits) of serial commands shall not be sent to the R/PA at a rate faster than one per 6 milliseconds.

4. There shall be a delay of one second minimum between successive serial data commands. Certain serial commands, listed below, require a delay greater than one second.

5. A Memory Diagnostic command must be followed by a delay of 30 seconds.

6. A Command Mode command must be followed by a delay of 60 seconds.

7. There shall be a one-second delay between R/PA Standby Power ON and R/PA OFF, between R/PA Main Power ON and R/PA OFF, and between R/PA OFF and R/PA Standby Power ON.

8. Each R/PA OFF command shall be followed by a second R/PA OFF command, delayed at least 100 milliseconds from the first. Also, prior to each R/PA Standby Power ON command, an R/PA OFF command shall be issued. These additional R/PA OFF commands are required to assure that the relay K8 has been switched to OFF.

9. There shall be a delay of one minute minimum after the START EXECUTE command SB40 prior to transmission of next command.

10. There shall be a delay of one second between transmission of STANDBY POWER ON command (834) and the MAIN POWER ON command (820).

11. The GPS Enable command shall be preceded by an R/PA OFF command and a one second delay.

12. If the R/PA has been placed into the Standby mode by an SC10 (Mode Select, go to Standby, return in Command mode) and Main Power ON is commanded. Subsequently, the R/PA will go to the Command mode. The Main Power ON command shall be followed by a 60 second delay.

15.7 RECEIVER/PROCESSOR ASSEMBLY (R/PA) TELEMETRY

15.7.1 GENERAL DESCRIPTION

The R/PA provides internal telemetry signals to allow determination of GPS Subsystem's general "health" and status. The telemetry points consist of single bilevel measurements for status, diagnostic and built-in test results. External and internal analog voltages, currents, temperatures, etc., are converted from analog to digital with a resolution of 8 bits binary. All telemetry points are multiplexed into a single serial output, that is available in Telemetry Serial Data File 4.

In addition to the composite digital telemetry data stream, a critical subset of telemetry data is made available in parallel format in direct analog or digital form (e.g., 10 analog functions plus 32 binary functions). This critical subset is available as long as standby power is applied to the R/PA. All the various R/PA operating modes, whether they are affected by discrete command, data command, or by automatic operation of the R/PA itself, are verified by discrete telemetry, and are included in the critical subset.

15.7.2 GPS TELEMETRY FORMAT - SERIAL DATA

The GPS Telemetry Format for Serial Data is shown in Figure 15.7-1. The Spacecraft Real Time Mission Telemetry Format for GPS data files consists of 11 minor frames (rows) of twelve 8 bit words (columns 17 thru 28). The Spacecraft Real Time engineering Telemetry Format consists of 25 minor frames (rows) of five 8 bit words (column 17 thru 21). The format for either mission or engineering data adds zero value words to fill the rows as needed to complete a Major Frame, and data files are separated by one row of zero value words.

15.7.3 CRITICAL TELEMETRY OUTPUT

The R/PA outputs 10 analog data measurements which are sampled by Landsat-D not less than once during each 10-second interval. There are up to 32 binary data measurements which are sampled by Landsat-D not less than once every 5 seconds The critical telemetry identification is shown in Table 15.7-2. L0 equals logic 0 state and L1 equals logical 1 state.

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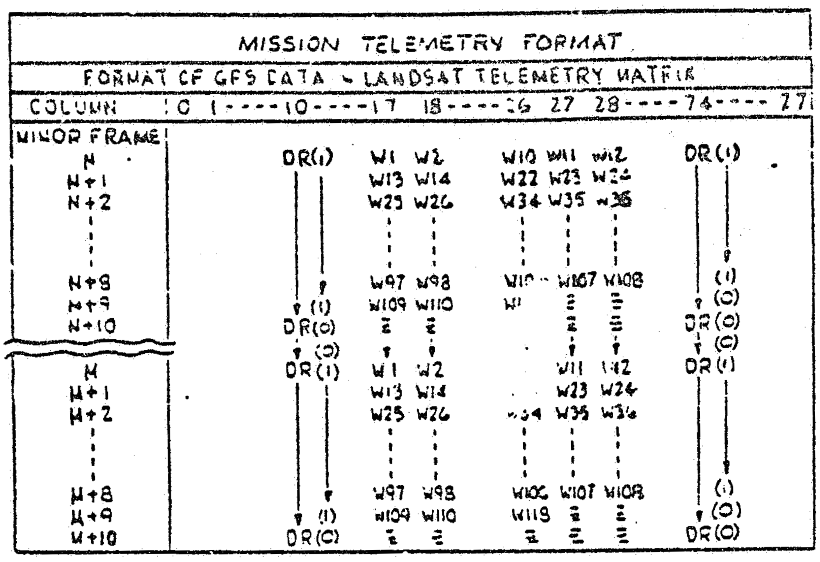

NOTES: 1. DR = DATA READY BI-LEVEL BIT. THIS WORD INCLUDES ALSO OVERRUN MODE STATUS, COMMAND PASS AND COMMAND FAIL BITS. (1) OR (0) REPRESENTS DR BIT VALUE

2. Z = TELEMETRY WORD VALUE EQUALS ZERO.

3. GPS FRAME M THROUGH M-10 MAY FOLLOW N-10 IMMEDIATELY DEPENDING ON HOW MANY GPS DATA FILES ARE REQUESTED.

4. IN ENGINEERING FORMAT, THE DATA READY WORD (DR) IS IN COLUMN 10 ONLY AND SERIAL DATA IS IN COLUMNS 17 THRU 21. ONE GPS FRAME CAN BE OUTPUT IN 25 MINOR FRAMES OF TELEMETRY.

5. TIME REQUIRED TO OUTPUT ONE GPS DATA FILE FRAME (118 WORDS OF GPS DATA) IS DEPENDENT ON TELEMETRY FORMAT AND DATA RATE, PER FOLLOWING TABLE:

TELEMETRY FORMAT	TIME REQUIRED FOR ONE GPS FRAME (INCLUDING MINOR FRAME OF ZERO'S	
	DATA RATE 8KBPS	DATA RATE 1KBPS
MISSION FORMAT	1.408 SECONDS	11.264 SECONDS
ENGINEERING FORMAT	3.2 SECONDS	25.6 SECONDS

Figure 15.7-1. Telemetry Format for Serial Data

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Table 15.7-2. Critical Telemetry Functions

Analog Functions

1. R/PA Power Supply +5 (standby)
2. R/PA Power Supply -12 (standby)
3. R/PA Power Supply +5
4. R/PA Power Supply -12 (Analog)
5. R/PA Power Supply Input Current
6. R/PA Power Supply Temperature
7. R/PA Analog Module Temperature
8. External Preamp Temperature
9. External Dual Oscillator Case Temperature
10. External Dual Oscillator Regulator Voltage

Binary Functions

Signal	Group	Description	STBY	LO	L1
1	SYSTEM STATUS	Mode Bit 1 *		X	X
2	SYSTEM STATUS	Mode Bit 2 *		X	X
3	SYSTEM STATUS	Mode Bit 3 *		X	X
4	SYSTEM STATUS	Mode Bit 4 *		X	X
5	SYSTEM STATUS	Initialization		OFF	INIT
6	SYSTEM STATUS	Propagate		OFF	PROP
7	SYSTEM STATUS	Almanac Collect		OFF	Collect
8	SYSTEM STATUS	Satellite Bit 1 **		Y	Y
9	SYSTEM STATUS	Satellite Bit 2 **		Y	Y

* Interpreted as a 4-bit binary number; X's denote the binary bits
8.7.4.1.4

** Interpreted as a 2-bit binary number; Y's denote the binary bits
8.7.4.1.8

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Table 15.7-2. Critical Telemetry Functions (Cont'd)

Binary Functions

Signal	Group	Description	STBY*	LO	HI
10	SW API	Invalid Transition		OFF	Alarm
11		Diagnostic Warning		OFF	Alarm
12		CMD Pass		OFF	Pass
13		CMD Fail		OFF	Fail
14		Bit Error	S	OFF	Error
15		Set Failure	S	OFF	Failure
16	HW STATUS	TCG Set/Run	S	SET	Run
17		R/PA Power	S	OFF	ON
18		Main Power	S	OFF	ON
19		OSC No.1	S	OFF	ON
20		OSC No.2	S	OFF	ON
21		Receiver Channel A		OFF	ON
22		Receiver Channel B		OFF	ON
23		Navigate/Command		CMD	NAV
24		DMA Receive		OFF	Ready
25		DMA Transmit		OFF	Ready
26	HW API	Memory Power Fail	S	OFF	Fail
27		AFI SYN Channel A		OFF	Fail
28		AFI RF/IF Channel A		OFF	Fail
29		AFI SYN Channel B		OFF	Fail
30		AFI RF/IF Channel B		OFF	Fail
31	EXT	EX DIG TLM 1	S	LOW	HIGH
32		EX DIG TLM 2	S	LOW	HIGH

*NOTE. S denotes the signals which function in Standby.

15.7.4 R/PA TELEMETRY

The R/PA health and status telemetry is available in Serial Data File 4 or directly via RIU #7. The functions of the critical subset that have meaning during STANDBY Mode remain available as long as standby power is applied to the R/PA. All operating modes of the R/PA, whether controlled by discrete commands, by data commands or by automatic operation of the R/PA, are verifiable by the analog or discrete telemetry. For details, see Appendix A, Volume II (Telemetry) Data Format Control Book.

15.7.4.1 R/PA Telemetry Descriptions

15.7.4.1.1 Data Ready Bit

The Data Ready bit indicates when a data file is provided by the R/PA serial output to the telemetry stream. When the bit is set to a logical 1, the R/PA outputs a data file starting with the next row available in the matrix allocation for the serial data output. When set to a logical 0, there is no R/PA data files ready for output and the R/PA outputs continuous zeroes in the matrix positions (rows) allocated for serial data file output. This bit can be used by the OBC to recognize data file availability. The Data Ready bit goes high, "1", in sync with the minor frame sync pulse.

15.7.4.1.2 Mode Status Bit

The Mode Status bit is either a logic 1 which is equal to the Computer mode of output (not used by Landat-D) or a logic 0 which is equal to the telemetry mode where each data file is 944 bits long and each data file must be separated by a row of zeros.

15.7.4.1.3 Overrun Bit

The Overrun bit is an indication of the R/PA memory buffer status in terms of its storing data files for subsequent telemetry output. When this bit is set to a logical 1, the R/PA buffer has overflowed and data file(s) is (are) lost; when set to a logical 0, the buffer is not full and overflow does not exist. This is the normal state of the buffer.

15.7.4.1.4 Mode Bits 1, 2, 3 and 4

These signals should be considered as a group forming a 4 bit binary number ranging from 0 through 15 decimal. Mode Bit 1 is the most significant bit (MSB); Mode Bit 4 is the least significant bit (LSB). These signals specify the current operational mode of the R/PA. The interpretation of each bit sequence is as follows:

Decimal Number	Mode Bit 1 2 3 4	Mode
0	0 0 0 0	STANDBY
1	0 0 0 1	SPARE
2	0 0 1 0	LOAD
3	0 0 1 1	PROPAGATE (COMMANDED)
4	0 1 0 0	COMMAND
5	0 1 0 1	GROUND
6	0 1 1 0	CAL
7	0 1 1 1	RTM
8	1 0 0 0	SPACE (ST, P, ND)
9	1 0 0 1	SPACE (ST, P, D)
10	1 0 1 0	SPACE (ST, C/A, ND)
11	1 0 1 1	SPACE (ST, C/A, D)
12	1 1 0 0	SPACE (TTFF, P, ND)
13	1 1 0 1	SPACE (TTFF, P, D)
14	1 1 1 0	SPACE (TTFF, C/A, ND)
15	1 1 1 1	SPACE (TTFF, C/A, D)

Where:

ST:	Sequential Track State
TTFF:	Time-to-first-fix State
P:	Tracking P Code
C/A:	TGracking C/A Code
D:	Data Demodulation Dwell
ND:	Non Data Demodulation Dwell

Mode Bit 1 functions as a SPACE/NON-SPACE mode indicator. In the SPACE mode, Mode Bits 2,3, and 4 indicate:

Mode Bit 2: Sequential-track/time-to-first-fix
Mode Bit 3: P Code / C/A code
Mode Bit 4: Data Dwell / Non-Data Dwell

15.7.4.1.5 Initialization Bit

The first portion of processing after a transition from COMMAND mode into any NAVIGATION mode (i.e., SPACE, etc.) is INITIALIZATION. This bit is set to the logic 1 state while the system is performing INITIALIZATION; it is at logic 0 otherwise.

15.7.4.1.6 Propagate Bit

The propagate status bit indicates when the R/PA is propagating the navigation solution and not updating it with ranging measurements. This can occur in 4 situations.

1. In COMMAND mode
2. In PROPAGATE mode
3. In ALMANAC COLLECT mode
4. In SPACE, GROUND, or CAL modes

    a. In TTFF prior to the first measurement attempt.

    b. In sequential track during a VCO calibration dwell.

    c. In sequential track during satellite changeover (while the receiver is acquiring a new satellite and demodulating its ephemeris data)

    d. In sequential track when there is a signal drop-out and no measurement occurs within the first six seconds of a dwell.

    e. When the number of satellites in view drops below a data base constant (Normally set to one), the receivers are powered off, no measurements are made, and the navigation solution is propagated.

15.7.4.1.7 Almanac Collect Bit

The Almanac Collect bit indicates when the R/PA is in the ALMANAC COLLECT mode. During this mode, the signal will be set to logic 1: otherwise, it will be kept at logic 0.

15.7.4.1.8 Sat Bits 1 and 2

These two status bits indicate the number of satellites currently being successfully tracked by the R/PA. The interpretation is as follows:

Sat Bit #1	Sat Bit #2	
0	0	Either 4 or 0 NDS being tracked
0	1	1 NDS being tracked
1	0	2 NDS being tracked
1	1	3 NDS being tracked

Note that the Propogate telemetry bit indicates whether the R/PA is propagating or navigating will distinguish between the 0 and 4 case. When 4 NDS are being successfully tracked, the set will not be propagating.

15.7.4.1.9 Invalid Transition Bit

The transition status bit provides a warning whenever the R/PA has been given a command to make a transition into a new mode but insufficient initialization data has been supplied. As an example, the R/PA could be commanded to enter the SPACE mode from COMMAND without a specification of the receiver configuration. When this situation occurs, the R/PA remains in its prior mode and this signal is set to logic 1. In normal operation, it is kept at logic 0. Once set, this signal will remain at logic 1 until either the required data is supplied or the mode transition request is aborted.

15.7.4.1.10 Diagnostic Warning Bit

The diagnostic status bit indicates that a non-fatal error condition has been detected by the R/PA and that diagnostic information has been placed in Serial Data File 4. In normal operation, this signal is in logic 0; when an error condition is detected, it is changed to logic 1. When data file 4 is output, the signal is reset to logic 0. The following will activate this warning signal:

1. When almanac collect has failed in four consecutive attempts.
2. When receiver processing detects that certain critical receiver parameters have exceeded nominal bounds but successful operation is still possible.
3. When navigation detects that the Kalman filter estimate is diverging during sequential track or when navigation errors during PROPAGATION exceed certain bounds.
4. When telemetry processing detects any hardware errors.
5. When analog telemetry processing detects any hardware errors.
6. When telemetry processing detects a telemetry buffer overrun condition.

15.7.4.1.11 CMD Pass, CMD Fail Bits

The CMD Pass and CMD Fail bits (Spacecraft Real Time Format) are used to indicate whether the last complete command message has been accepted as correct by the R/PA software; this means that all consistency checking for each command block headers, the sequence of arrival of command blocks, and the message checksum have all passed. These signals are set during both Load and Command modes of operation. These two signals are cleared by Set hardware when either 1) the next data command is received, or 2) five minor frame pulses have been received by the R/PA.

The interpretation of the 2 bit pass/fail combinations are as follows:

CMD Pass Bit	CMD Fail Bit	
0	0	Power-up value, or have been cleared for either of two reasons above.
1	0	Last message received has passed software check.
0	1	Last message received has failed software check.
1	1	Illegal combination. Its occurrence is due to Set hardware when powering up or software error.

These signals are dormant during STANDBY.

15.7.4.1.12 Built In Test (BIT) Error Bit

This bit in the telemetry stream is set to logical 1 when the Built In Test function detects a fatal software error. Detecting a BIT error causes the R/PA to transfer (under software control) to STANDBY Mode. The error bit is reset to logical 0 by hardware during powerup.

15.7.4.1.13 Set Failure Bit

The Set Failure status bit indicates a critical condition.

When a critical software condition is detected the Set Failure bit is set to logical 1 and the R/PA transfers to STANDBY Mode. It is returned to logical 0 upon powerup. The following will activate the Set Failure bit:

1. When satellite data gathering detects an illegal mode.

2. When receiver processing detects that certain receiver parameters have exceeded allowable bounds and data is suspect.

3. When navigation processing detects that the filter has diverged to the point that successful resumption of navigation is improbable.

15.7.4.1.14 TCG SET/Run Bit

The TCG Set/Run telemetry bit is the output of a solid satate latch controlled by TCG Set (P9) and TCG Run (P10) discrete commands. TCG Set/Run is used to indicate whether the TCG timer is running or stopped. TCG Set/Run goes to logic 0 whenevere the TCG Set pulse command is received, and stops the TCG counter.

TCG Set/Run goes to a logic 1 whenever the TCG Run pulse is received, and starts the TCG counter.

15.7.4.1.15 R/PA Power Bit

The R/PA Power telemetry bit is used to indicate when STANDBY Power is on. The state of this telemetry bit is controlled with the power ON discrete command (P2) and power OFF discrete command (P1). The power ON pulse sets this signal to logic 1. The power OFF pulse command shuts all power off and sets this signal to logic 0.

15.7.4.1.16 Main Power Bit

The Main Power telemetry bit is used to indicate whether Main Power is on or off. When Main Power is ON, this signal will be at logic 1. When Main Power is OFF, it will be at logic 0.

15.7.4.1.17 OSC #1, OSC #2 Bits

OSC #1 and OSC #2 bits are used to indicate which Reference Oscillator is powered ON. The GPS Subsystem used aboard LANDSAT has only one Oscillator. The relay contacts used select either OSC #1 or OSC #2 are strapped together and the OSC #1 bit and the OSC #2 bits are set to 1.

15.7.4.1.18 Receiver Channel A and Receiver Channel B Bits

These two bits are used to indicate when power to each receiver channel (A and B) is ON or OFF. Turning receiver power ON or OFF is fully controlled by software. These two telemetry bits are dormat during STANDBY since receiver power is turned off. On powering backup, the R/PA HARDWARE automatically shuts both receiver channel power relays OFF. The interpretation of these two signals bits is as follows:

CH A	CH B	
0	0	Channel A power OFF; Channel B power OFF
1	0	Channel A power ON; Channel B power OFF
0	1	Channel A power OFF; Channel B power ON
1	1	Channel A Power ON; Channel B power ON

15.7.4.1.19 SPA/CMD Bit

The SPA/CMD bit monitors the status of the relay (latch L2) which controls whether the R/PA is in COMMAND or SPACE mode. The state of this relay is controlled by the Command Mode discrete command (P5) and SPACE Mode pulse command (P6). A logic 0 state indicates that the R/PA should be in COMMAND mode. A logic 1 state indicates that the R/PA should be in SPACE mode. After a power down to STANDBY, the R/PA hardware resets this relay to COMMAND mode when the set is powering up.

15.7.4.1.20 DMA Receive Bit

The DMA bit indicates when the telemetry module Direct Memory Access (DMA) hardware has been correctly initialized by software to accept serial data commands from the C&DH subsystem to the R/PA. This signal will be set to logic 1 whenever the R/PA is in the LOAD or COMMAND mode of operation and can accept data commands. When this signal is at logic 0, the R/PA is not properly set to accept data commands.

15.7.4.1.21 DMA Transmit Bit

The DMA Transmit bit indicates that the telemetry module DMA hardware has been properly set by software to perform serial data transfers from the R/PA to the C&DH Subsystem. When this bit is set to logic 1, the R/PA has data files for transmission to the C&DH Subsystem. The telemetry module hardware resets this signal to logic 0 after all serial bits of a data block have been transferred. The telemetry module sets a failure flag indicating the type of hardware failure that occurred. When this signal is at logic 0, the DMA transmit hardware is not set up to output data files to the C&DH Subsystem.

15.7.4.1.22 MEM PWR Fail Bit

The MEM PWR Fail bit monitors the R/PA Ram memory power (+5V STDBY). If a power transient occurs on this line which drives the voltage below memory retain threshold 2.5 volts, the memory contents would probably become invalid and require reloading. This signal will be set to logic 1 whenever such an event happens; its nominal state is logic 0. The R/PA hardware monitors the state of this signal and automatically transfers the system into the LOAD mode (instead of COMMAND) when the R/PA goes through a power-up sequence on Main Power. Once the R/PA is in the LOAD mode, this signal is reset to logic 0.

15.7.4.1.23 SYN and RF/IF AFI Bits

Two bits for hardware AFI are allocated to each receiver channel. One monitors the synthesizer; the otehr monitors the RF/IF. The assignments are as follows:

SYNTHESIZER ARI - CHANNEL A
RF/IF AFI - CHANNEL A
SYNTHESIZER AFI - CHANNEL B
RF/IF AFI - CHANNEL B

Nominal "good" performance will produce a logic 0 condition; a failure will cause a logic 1 state. The synthesizer contains four fault detectors which are "OR"ed together to provide a single output indicating a fault. These four detectors monitor the 29 1/2F, 68 F, F_{ct}, and 2 F_{ct} harmonics. If any of these signals fall 6 dB below nominal, a fault indication will result. The RF/IF module will indicate a fault when its output signal level falls more than 6 dB below the noise level of the module alone (no preamp); this indicates insufficient gain.

15.7.5 DATA FILE GENERATION

The System Output Telemetry contains the R/PA navigation Data and is organized in 12 data files. It is possible, by data command, to set the rate at which each data file is placed in an R/PA buffer. The basic output rate of each data file is once per Navigation cycle period (nominally 6 seconds). It is possible, by transmitting an appropriate file index to the R/PA, to change the "Buffer Fill" rate of each data file to some integer multiple of the Navigation cycle period A file index of 0 will cause the R/PA to inhibit the transmission of data from the file to the buffer. The data file identification, Output Mode and Drivers are shown in Table 15.7-3.

Table 15.7-3. Serial Data Output Files (1)

File ID	Frame ID	File Name	Output(2) Mode	Output(3) Drive
0	1,2,3--	Command Echo Buffer	C	DC
1	1	Memory Load Bit Map	L	DC
2	1,2,3--	R/PA Memory Contents	C or L	DC
3	1	Current Operating Ephemeris	N	E_1 & F
4	1	System Status	N	F
5	1	NDS Almanacs	N	E_2 & F
5	2	NDS Almanacs	N	E_2 & F
5	3	NDS Almanacs	N	E_2 & F
5	4	NDS Almanacs	N	E_2 & F
5	5	NDS Almanacs	N	E_2 & F
6	1	Time Marks(4)	-	
7	1	Navigation Best Estimate(4)	N	E_3 & F
8	1	Kalman Input	N	F
9	1	Raw Receiver Measuremens	N	E_4 & F
10	1	Compressed Measurement Data	N	F
11	1	Receiver Diagnostic Data	N	E_5 & F

NOTES:

(1) Each data file is 944 bits.

(2) in Output Mode column; C=Command Mode, L=Load Mode, N= a Navigation Mode

(3) in Output Drive column; DC=Serial Data Command, E=Event, F=File Index>zero.

Individual Events are:
E_1 = when new ephemeris is collected from newly-acquired NDS.
E_2 = when a complete NDS almanac is collected
E_3 = when the time mark buffer fills
E_4 = when a receiver measurement is taken
E_5 = when receiver diagnostic processing is complete

(4) File 6 is not used on Landsat-D. File 7 contains Time Marks.

(5) F is a File Index set by the SET FILE INDEX which is an operational Data Command previously uplinked from the ground.

15.7.5.1 Serial Data File 0 - Command Echo Buffer Data

Data File 0 contains the Echo Buffer information which is transmitted in the format shown in Table 15.7-4. This file is available when the Set is in the COMMAND Mode and is output to telemetry upon uploading the ECHO DATA COMMAND BUFFER Operational Data Command (1E11).

15.7.5.2 Serial Data File 1 - Memory Load Bit Map

Data File 1 contains the Memory Load Bit Map information which is transmitted in the format shown in Table 15.7-5. This file is available when the Set is in the LOAD Mode and is output to telemetry upon uploading the BIT MAP OUTPUT Loader Data Command (402).

15.7.5.3 Serial Data File 2 - R/PA Memory Dump

Data File 2 contains the R/PA Processor Memory information and is transmitted in the format shown in Table 15.7-6. This file is available in either the COMMAND Mode or the LOAD Mode and is output to telemetry upon receipt of the MEMORY DUMP Loader Data Command (405) or upon receipt of the MEMORY DUMP Operational Data Command (1E9).

15.7.5.4 Serial Data File 3 - Current Operating Ephemeris

Data File 3 contains the current NDS Satellite operating ephemeris information which is transmitted in the format defined in Table 15.7-7. It is available in the SPACE Mode and when a new ephemeris is available from the current NDS Satellite. Data File 3 output to telemetry is controlled by the File Index number set by a previously uploaded SET DATA FILE INDEX Operational Data Command.

15.7.5.5 Serial Data File 4 - System Status

Data File 4 contains the System Status information and is transmitted in the format shown in Table 15.7-8. Output to telemetry is controlled by the File Index number which has been set by a previously uploaded SET DATA FILE INDEX Operational Command (1E3).

15.7.5.6 Serial Data File 5 - NDS Almanacs

Data File 5 is made up of 5 Frame ID and contains the NDS Almanacs for all NDS satellites. File 5 is available in the SPACE Mode when a complete NDS almanac has been collected from the current NDS satellite. The format is defined in Table 15.7-9 and the output to telemetry is controlled by the FILE INDEX number set by a previously uploaded SET DATA FILE INDEX Operational Data Command (1E3).

15.7.5.7 Serial Data File 6 - Time Mark(s)

Data File 6 is not used by LANDSAT-D and the TIME MARKS normally transmitted by Data File 6 are included in the Data File 7 informatin.

15.7.5.8 Serial Data File 7 - Navigation Best Estimate

Data File 7 contains the best estimate of the spacecrafts navigation state. It is available in the SPACE Mode when the time mark buffer files and is transmitted in the format shown in Table 15.7-10. The output to telemetry is controlled by the FILE INDEX number set by a previously uploaded SET DATA FILE INDEX Operational Data Command (1F3)

15.7.5.9 Serial Data File 8 - Kalman Input

Data File 8 contains the Kalman filter input information which is transmitted in the format described in Table 15.7-11, Data File 8 is available in the SPACE Mode. Output to telemetry is controlled by the File Index number set by a previously uploaded SET DATA FILE INDEX Operational Data Command (1E3). Table 15.7-12 shows the coded data for Data Files 7 and 15.

15.7.5.10 Serial Data File 9 - Raw Receiver Measurements

Data File 9 contains the raw receiver measurements which are transmitted in the format described in Table 15.7-3. The information is available in the SPACE Mode when a receiver measurement is completed. Output to telemetry is controlled by the File Index number set by a previously uploaded SET DATA FILE INDEX Operational Data Command (1E3).

15.7.5.11 Serial Data File 10 - Compressed Measurement Data

Data File 10 contains the information defined in Table 15.7-14. It is available in SPACE Mode and Output to telemetry is controlled by the File Index number set by a previously uploaded SET DATA FILE INDEX Operational Data Command (1E3).

15.7.5.12 Serial Data File 11 - Receiver Diagnostic Data

Data File 11 contains the receiver diagnostics which are transmitted in the format described in Table 15.7-15. Data File 11 is available in the SPACE Mode and its output to telemetry is controlled by the File Index number set by a previously uploaded SET DATA FILE INDEX Operational Data Command (1E3).

Table 15.7-4. Data File 0 Definition: Command Echo Data Buffer

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 0	4	1	15	None
Frame ID = 1, 2, 3---	8	1	255	None
EOT Indicator	16	1	0,-1	None
Checksum	16	NA	NA	NA
Command Block 1	40	NA	NA	NA
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Command Block 22	40	NA	NA	NA
*Total	944			

NOTES:

1. This file can be output only when R/PA is in command mode. Due to half-duplex mode of operation, the R/PA shall ignore data commands during the time required to output this file. Therefore, no data commands should be uplinked after issuance of the data command which causes this file to be output, until transmission of the file has been completed.
2. Zeros shall be transmitted for all or a portion of a frame if the buffer is not full.
3. Buffer is zeroed after transmission.
4. See section 3.8 for further information on the Command Echo Buffer.

*5. R/PA shall provide capability by software control to include "zero fill" in file, on an option basis, as indicated.

6. The EOT Indicator is set to -1, for the last frame of the file and is zero otherwise.

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Table 15.7-5. Serial Data File 1 Definition: Memory Load Bit Map

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 1	4	1	15	None
Frame ID = 1	8	1	255	None
Word 1	16	NA	NA	NA
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Word 56	16	NA	NA	NA
Zeros	16			
*Total	944			

NOTES: 1. Bit 1 of Word 1 corresponds to the value of a Memory Load Block Checksum for the memory block starting at R/PA location 0. Each other bit in a word represents the checksum for an upload of 64 16-bit memory words.

2. This file can be output only when R/PA is in the Load Mode. Due to half-duplex mode of operation, the R/PA shall ignore data commands during the time required to output this file.

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Table 15.7-6. Data File 2 Definition: R/PA Memory Contents

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 2	4	1	15	None
Frame ID = 1, 2, 3	8	1	255	None
EOT Indicator	16	1	0,-1	None
Checksum	16	NA	NA	NA
Starting Location	16	NA	NA	NA
Word (starting location)	16	NA	NA	NA
Word (starting location -1)	16	NA	NA	NA
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Word (starting location -53)	16	NA	NA	NA
=Total	944			

NOTES: 1. This file can be output only when the R/PA is in the command mode or the boot loader mode. Due to half-duplex mode of operation, the R/PA shall ignore data commands during the time required to output this file. Therefore, no data commands should be uplinked after issuance of the data command which causes this file to be output, until transmission of the file has been completed.

2. The EOT Indicator is set to -1 for the last frame of the file, and is zero otherwise.

Table 15.7-7. Data File 3 Definition: Current Operating Ephemeris

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 3	4	1	15	None
Frame ID = 1	8	1	255	None
Checksum	16	NA	NA	NA
NDS ID of new satellite ephemeris	8	1	255	None
Unpacked Data Block I	192			
Packed Data Block II	384			
Zeros	8			
*Zero fill				
	944			

NOTES: 1. This file is transmitted when a new ephemeris is available if the file index is greater than zero.

Table 15.7-7. Data File 3 Definition: Current Operating Ephemeris

Unpacked Data Block I

	Bits	LSB	Range*	Units
Group Delay Time $-T_{GD}$	32	2^{-31}	$\pm 2^{-24}$	sec
Age of Clock Data in Data Block I-AODC	32	2^{11}	524,288	sec
Reference GPS Time Since Weekly Epoch $-t_{oc}$	32	2^{4}**	604,784	sec
Clock Correction Polynomial Coefficient $-a_2$	32	2^{-55}	$\pm 2^{-48}$	sec/sec^2
Clock Correction Polynomial Coefficient $-a_1$	32	2^{-43}	$\pm 2^{-28}$	sec/sec
Clock Correction Polynomial Coefficient $-a_0$	32	2^{-31}	$\pm 2^{-10}$	sec
Total	192			

* (±) indicates that the sign bit shall occupy the most significant bit (MSB).

** The accuracy of this term is greater than indicated by its LSB because the LSB is not truncated or rounded.

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Table 15.7-7. Data File 3 Definition: Current Operating Ephemeris

Packed Data Block II

	Bits	LSB	Range*	Units
Age of the ephemeris data in this block (SF1) - AODE	8	2^{11}	524,288	sec
Harmonic coefficient for satellite radius correction - C_{rs}	16	2^{-5}	±1024	meters
Incremented correction to mean motion - Δn	16	2^{-43}	$\pm 4 \times 10^{-9}$	semicircles/sec
Mean anomaly at time t_{oe} - M_o	32	2^{-31}	±1	semicircles
Harmonic coefficient for the argument of latitude correction - C_{uc}	16	2^{-29}	$\pm 6 \times 10^{-5}$	radians
Eccentricity of orbit - e	32	2^{-33}	.5	dimensionless
Harmonic coefficient for the argument of latitude correction - C_{us}	16	2^{-29}	$\pm 6 \times 10^{-5}$	radians

Table 15.7-7. Data File 3 Definition: Current Operating Ephemeris

Packed Data Block II

	Bits	LSB	Range*	Units
The square root of the semi-major axis of the orbit $\sqrt{a}$	32	2^{-19}	8192	meters$^{\frac{1}{2}}$
GPS time of applicability of ephemeris data in this block - t_{oe}	16	2^{4**}	604,784	seconds
Spare (2 bits parity)	8	NA	NA	NA
Harmonic coefficients for orbit inclination correction - C_{ic}	16	2^{-29}	$\pm 6 \times 10^{-5}$	radians
Right ascension of the ascending node at time t_{oe} - Ω_o	32	2^{-31}	± 1	semicircles
Harmonic coefficients for orbit inclination correction - C_{is}	16	2^{-29}	$\pm 6 \times 10^{-5}$	radians
Inclination of orbit -	32	2^{-31}	± 1	semicircles

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Table 15.7-7. Data File 3 Definition: Current Operating Ephemeris

Packed Data Block II

	Bits	LSB	Range*	Units
Harmonic coefficient for satellite radius correction - C_{rc}	16	2^{-5}	±1024	meters
Argument of perigee - ω	32	2^{-31}	±1	semicircles
Drift rate of the right ascension - $\dot{\Omega}$	24	2^{-43}	5×10^{-5}	semicircles/sec
Age of the ephemeris data in this block (SF2) - AODE	8	2^{11}	524,288	sec
Spare	16	NA	NA	NA
Total	384			

* (±) indicates that the sign bit shall occupy the MSB.

** The accuracy of this term is greater than indicated by its LSB because the LSB is not truncated or rounded.

Table 15.7-8. Data File 4 Definition: System Status

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 4	4	1	15	NA
Frame ID = 1	8	1	255	NA
Checksum	16	NA	NA	NA
Time (TCG)	48	1+1.023	$2^{45}-1$	usec[3]
Receiver Diagnostics	32	NA	NA	NA
Navigation Diagnostics	48	NA	NA	NA
System Monitor Diagnostics[4]	8	1	255	NA
Telemetry Hardware Diagnostics[5]	8	1	255	NA
Analog Hardware Diagnostics[6]	8	1	255	NA
Bit Error Rate[7]	32	1	NA	NA
Telemetry Buffer Overrun	8	1	255	NA
Digital Critical TLM	32	NA	NA	NA
Analog TLM	128	NA	NA	NA
HV Almanac	160	NA	NA	NA
HV Almanac Checksum Error[8]	8	1	255	NA
Zeros	72	NA	NA	NA
Zero Fill[2]	304	NA	NA	NA
Total[2]	944			

NOTES:
1 This file is transmitted as indicated by file index.

2 R/PA shall provide capability by software control to include "zero fill" in file, on an option basis, as indicated.

3 TCG time is the time that telemetry formats this file. LSB 20 bits are zero; only MSB 25 bits have meaning.

4 Represents physical ID of satellite on which almanac collect failed (8-bit integer).

5 Flag to indicate hardware error detected by telemetry processing.

6 Flag to indicate hardware error detected by analog telemetry processing.

7 Number of demodulated data words with no parity error (16-bit integer) and number of demodulated data words with parity errors (16-bit integer).

8 Flag to indicate error in checksum computation.
1 = Error
0 = No Error

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Table 15.7-8. Data File 4 Definition: System Status

Receiver Diagnostics

Bit No.	Description
1 (MSB)	VCO Calibrate
2	VCO Linearity Test
3	Control Loop Bias Test L1-P
4	Control Loop Bias Test L1-C/A
5	Control Loop Bias Test L2-P
6	Search Rate Test L1-P
7	Search Rate Test L1-C/A
8	Search Rate Test L2-P
9	Slew Rate Test
10	Rate Aiding Test
11	Signal Test - 1ms Data Demodulation
12	Signal Test - 20 ms Data Demodulation
13	Signal Test - Code Sync
14	Signal Test - Costas Lock
15	Signal Test - Detection
16 (LSB)	Signal Test - Drift

NOTE: 1. Logical 1 means warning threshold exceeded for this test.
2. These 16 tests are run for Channel 1 and Channel 2.

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Table 15.7-8. Data File 4 Definition: System Status

Navigation Diagnostics

Test No. *	Description **
0	No warning.
1	Velocity variance exceeds threshold.
2	Position variance exceeds threshold.
3	Residual ratio exceeds threshold.

* Note 1: 16-bit integer value.
** Note 2: 32-bit real value.

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Table 15.7-8. Data File 4 Definition: System Status

Digital Critical TLM

Signal	Description	Signal	Description
1	Mode Bit 1 *	24	DMA Receive
2	Mode Bit 2 *	25	DMA Transmit
3	Mode Bit 3 *	26	Memory Power Fail
4	Mode Bit 4 *	27	AFI SYN Channel A
5	Initialization	28	AFI RF/IF Channel A
6	Propagate	29	AFI SYN Channel B
7	Almanac Collect	30	AFI RF/IF Channel B
8	Satellite Bit 1 **	31	EX DIG TLM 1
9	Satellite Bit 2 **	32	EX DIG TLM 2
10	Invalid Transition		
11	Diagnostic Warning		
12	Thrust Flag		
13	Not Used (Spare)		
14	Bit Error		
15	Set Failure		
16	TCG SET/RUN		
17	R/PA Power		
18	Main Power		
19	OSC No.1		
20	OSC No.2		
21	Receiver Channel A		
22	Receiver Channel B		
23	Navigate/Command		

* Interpreted as a 4-bit binary number; See section 3 7.4.1.4
** Interpreted as a 2-bit binary number; See section 8.7.4.1.8

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Table 15.7-8. Data File 4 Definition: System Status

Analog Telemetry

	Bits	LSB	Range	Units
R/PA Power Supply +5 (standby)	8	2^{-5}	7	Volts
R/PA Power Supply +12 (standby)	8	2^{-4}	15	Volts
R/PA Power Supply +5	8	2^{-5}	7	Volts
R/PA Power Supply +12 (Analog)	8	2^{-4}	15	Volts
R/PA Power Supply Input Current	8	2^{-5}	7	Amps
R/PA Power Supply Temperature	8	2^{-5}	7	Volts
R/PA Analog Module Temperature	8	2^{-5}	7	Volts
Ext. Preamp Temperature	8	2^{-5}	7	Volts
Ext. Dual Oscillator Case Temperature	8	2^{-5}	7	Volts
Ext. Dual Oscillator Reg. Voltage	8	2^{-4}	15	Volts
Ext. Oscillator #1 Flask Temperature	8	2^{-5}	7	Volts
Ext. Oscillator #2 Flask Temperature	8	2^{-5}	7	Volts
Ext. Dual Oscillator Heater Voltage	8	2^{-3}	31	Volts
Ext. Analog TLM 1	8	2^{-5}	7	Volts
Ext. Analog TLM 2	8	2^{-5}	7	Volts
Ext. Analog TLM 3	8	2^{-5}	7	Volts
Total	128			

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Table 15.7-8. Data File 4 Definition: System Status

EV Almanac

	Bits	LSB	Range	Units
Eccentricity of orbit - e	16	2^{-17}	2^{-1}	None
Time of applicability of almanac parameters - t_{oa}	8	2^{12}	602,112	sec
Inclination of orbit - i_o	24	2^{-23}	±1	semicircle
Drift rate of longitude of ascending node of orbit - $\dot{\Omega}$	16	2^{-38}	2^{-23}	semicircle/sec
Square root of semi-major axis of orbit - $\sqrt{a}$	24	2^{-11}	2^{13}	$(\text{meters})^{\frac{1}{2}}$
Longitude of ascending node of orbit at t_{oa} - Ω_o	24	2^{-23}	±1	semicircle
Argument of perigee - ω	24	2^{-23}	±1	semicircle
Mean anomaly at t_{oa} - M_o	24	2^{-23}	±1	semicircle
Total	160			

15.7-9. Data File 5 Definition: NDS Almanacs

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 5	4	1	15	None
Frame ID = 1	8	1	255	None
Checksum	16	NA	NA	NA
NDS Almanac 1	184			
NDS Almanac 2	184			
NDS Almanac 3	184			
NDS Almanac 4	184			
NDS Almanac 5	144		(PID - ω)	
Zeros	16			
*Frame Total	944			
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 5	4	1	15	None
Frame ID = 2	8	1	255	None
Checksum	16	NA	NA	NA
NDS Almanac 5	40		(M_o - a_1)	
NDS Almanac 6	184			
NDS Almanac 7	184			
NDS Almanac 8	184			
NDS Almanac 9	184			
NDS Almanac 10	120		(PID - Ω_o)	
*Frame Total	944			

15.7-9. Data File 5 Definition: NDS Almanacs

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 5	4	1	15	None
Frame ID = 3	8	1	255	None
Checksum	16	NA	NA	NA
NDS Almanac 10	64		$(\omega - a_1)$	
NDS Almanac 11	184			
NDS Almanac 12	184			
NDS Almanac 13	184			
NDS Almanac 14	184			
NDS Almanac 15	96		$(PID - \sqrt{a})$	
*Frame Total	944			
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 5	4	1	15	None
Frame ID = 4	8	1	255	None
Checksum	16	NA	NA	NA
NDS Almanac 15	88		$(\Omega_0 - a_1)$	
NDS Almanac 16	184			
NDS Almanac 17	184			
NDS Almanac 18	184			
NDS Almanac 19	184			
NDS Almanac 20	72		(PID - SEV)	
*Frame Total	944			

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15.7-9. Data File 5 Definition: NDS Almanacs

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 5	4	1	15	None
Frame ID = 5	8	1	255	None
Checksum	16	NA	NA	NA
NDS Almanac 20	112		$(\sqrt{a} - a_1)$	
NDS Almanac 21	184			
NDS Almanac 22	184			
NDS Almanac 23	184			
NDS Almanac 24	184			
Zeros	48			
Frame Total	944			
File Total	4720			

NOTES:

1. This file is generated when a new almanac is collected if the file index is greater than zero.

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15.7-9. Data File 5 Definition: NDS Almanacs

NDS Almanac Data

	Bits	LSB	Range	Units
Satellite ID - PID	8	2^0	255**	NA
Eccentricity of Satellite orbit - e	16	2^{-21}	2^{-5}	dimensionless
Time of applicability of the almanac parameters to this block III - t_{oa}	8	2^{12}	602,112	sec
Satellite orbit inclination increment - Δi	16	2^{-19}	$\pm 2^{-4}$	semicircles
Drift rate of longitude of ascending node of the orbit - $\dot{\Omega}$	16	2^{-38}	$\pm 2^{-23}$	semicircles/sec
Health - SHV	8	2^0	255	NA
The square root of the semi-major axis of the orbit - $\sqrt{a}$	24	2^{-11}	2^{13}	$(\text{meters})^{\frac{1}{2}}$
Longitude of ascending node of orbit at t_{oa} - Ω_o	24	2^{-23}	± 1	semicircles

** The allowed range on satellite ID is 0 to 33.

15.7-9. Data File 5 Definition: NDS Almanacs

NDS Almanac Data

	Bits	LSB	Range	Units
Argument of perigee - ω	24	2^{-23}	± 1	semicircles
Mean anomaly at t_{oa} - M_o	24	2^{-23}	± 1	semicircles
Satellite clock bias - a_o	8	2^{-17}	$\pm 2^{-10}$	sec
Satellite Clock Drift - a_1	8	2^{-35}	$\pm 2^{-28}$	sec/sec
Total	184			

Table 15.7-10. Data File 7 Definition: Navigation Best Estimate

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 7	4	1	15	None
Frame ID = 1	8	1	255	None
Checksum	16	NA	NA	NA
T_{R1}(TCG)	48	1÷1.023	$2^{45}-1$	μsec
Time (GPS)	48	2^{-28}	2^{20}	sec
X ECEF Position	48		**	meter
Y ECEF Position	48		**	meter
Z ECEF Position	48		**	meter
X ECEF Velocity	32		*	meter/sec
Y ECEF Velocity	32		*	meter/sec
Z ECEF Velocity	32		*	meter/sec
UTC Clock Bias (b).	32		*	meter
UTC Clock Bias Rate ($\dot{b}$)	32		*	meter/sec
Drag Constant ($C_o A/2m$)	32		*	$meter^2/kg$
Position Variance	32		*	$meter^2$
Velocity Variance	32		*	$(meter/sec)^2$
Clock Bias Variance	32		*	$meter^2$
Clock Bias Rate Variance	32		*	$(meter/sec)^2$
Coded Data	32	See Table 8-18	(CODED DATA)	
No. of Valid time marks	16			
Six time marks at 48 bits each	288			
Total	944			

NOTES:
1. * Single Precision Floating Point Number.
2. ** Double Precision Floating Point Number.
3. Deleted.
4. This file format is used to generate data file 7 for the LANDSAT-D GUSCP application. This file is formatted by file index or when the time mark buffer fills if the file index is greater than zero.
5. T_{R1}(TCG) shall equal zero if the R/PA is propagating with the receiver on after set time from HOW.

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Table 15.7-11. Data File 8 Definition: Kalman Input

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 8	4	1	15	None
Frame ID = 1	8	1	255	None
Checksum	16	NA	NA	NA
Primary Channel				
NDS Number	8	1	255	None
Zeros	8			
T_{R1}(TCG)	48	1÷1.023	$2^{45}-1$	μsec
PR_1	48		**	meter
T_{X1}(GPS)	48	2^{-28}	2^{20}	sec
T_{R1}(UTC)	48	2^{-28}	2^{20}	sec
ΔPR	32		*	meter
T_{X2}(GPS)	48	2^{-28}	2^{20}	sec
T_{R2}(UTC)	48	2^{-28}	2^{20}	sec
Coded Data	32	See Table	(CODED DATA)	
PRES	32		*	meter
DRES	32		*	meter
***Zero Fill				
***Total	944			

NOTES:
1. * Single Precision Floating Point Number.
2. ** Double Precision Floating Point Number.
3. *** R/PA shall provide capability by software control to include "zero fill" in file, on an option basis, as indicated.
4. Deleted.
5. This file is formatted as specified by file index.
6. T_{R1}(TCG) shall equal zero if the R/PA is propagating with the receiver on after set time from HOW.

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Table 15.7-12. Dat File 7 and 8 Definition of Coded Data

Bit Number (MSB-LSB)		Bits	Type
1, 2	Satellite Bits	2	INTEGER (0-3)*
3	Almanac/Ephemeris Flag	1	1 = Almanac, 0 = Ephemeris
4, 5	Delta-Pseudorange Meas. Quality Flag (DCODE)	2	INTEGER (0-3)
6 - 9	Pseudorange Meas. Quality Flag (RCODE)	4	INTEGER (0-15)
10-15	NDS ID	6	INTEGER (0-63)
16	Propagate Flag	1	1 = Propagate, 0 = No Propagate
17-24	Delta-Pseudorange Residual Ratio	8	INTEGER (0-255)**
25-32	Pseudorange Residual Ratio	8	INTEGER (0-255)**
	Coded Data Total	32	

* Same as critical TLM satellite bits.

** Ratios scaled by multiplication by 10 before integerizing. Range of coded residual ratios is 0.1 to 25.5.

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Table 15.7-13. Data File 9 Definition Raw Receiver Measurements

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 9	4	1	15	None
Frame ID = 1	8	1	255	None
Checksum	16	NA	NA	NA
Primary Channel				
NDS Number	8	1	255	None
Zeros	8			
- L1 -				
T_{R1}(TCG)	48	1÷1.023	$2^{45}-1$	μsec
RIONO	32	-	*	P CHIPS
CT1	32	1	30240000	20ms
CP1	48	-	**	P CHIPS
CT2	32	1	30240000	20ms
CP2	48	-	**	P CHIPS
- L2 -				
CT1	32	1	30240000	20ms
CP1	48	-	**	P CHIPS
CT2	32	1	30240000	20ms
CP2	48	-	**	P CHIPS
A_0	32	2^{-31}	$\pm 2^{-10}$	sec
A_1	32	2^{-43}	$\pm 2^{-28}$	sec/sec
A_2	32	2^{-55}	$\pm 2^{-48}$	sec/sec^2
TOC	32	***	604,784	sec
CODES				
RCODE	8	1	255	NA
DCODE	8	1	255	NA
Mode Qualifier	8	1	255	NA
Iono Qualifier	8	1	255	NA
Zeros	16			
Zero Fill	304			
Total	944			

NOTES:
1. * Single Precision Floating Point Number.
2. ** Double Precision Floating Point Number.
3. *** The accuracy of this term is > than indicated by its LSB because the LSB is not truncated or rounded.
4. Deleted.
5. See DFCB for algorithms that utilize these values.
6. This file is generated when a receiver measurement is taken if the file index is greater than zero.
7. T_{R1} (TCG) shall equal zero if the R/PA is propagating with the receiver on after set time from HOW.
8. Mode Qualifier:
   0 = Single channel iono data.
   1 = Dual channel iono data.
9. Iono Qualifier:
   0 = Iono data not valid.
   1 = Iono data valid.

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Table 15.7-14. Data File 10 Definition Compressed Measurement Data

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 10	4	1	15	None
Frame ID = 1	8	1	255	None
Checksum	16	NA	NA	NA
First NDS Primary Channel				
NDS Number	8	1	255	None
T_{R1}(TCG)	48	1÷1.023	$2^{45}-1$	μsec
PR_1	48		**	meter
T_{X1}(GPS)	40	2^{-20}	2^{20}	sec
ΔPR	32		*	meter
ΔT_X(GPS)	24	2^{-20}	2^{4}	sec
CODES				
RCODE	8	1	255	NA
DCODE	8	1	255	NA
Second NDS Primary Channel	216			
Third NDS Primary Channel	216			
Fourth NDS Primary Channel	216			
Zeros	32			
Total	944			

NOTES:

1. * Single Precision Floating Point Number.
2. ** Double Precision Floating Point Number.
3. Deleted.
4. Times of reception may be computed from the file 10 data using the following equations:

   $$TR_1(UTC) = T_{X1}(GPS) + PR_1/C \quad C = \text{speed of light.}$$

   $$TR_2(UTC) = T_{X1}(GPS) + \Delta Tx(GPS) + \frac{PR_1 + \Delta PR}{C}$$

5. This file is formatted as specified by file index.
6. T_{R1}(TCG) shall equal zero if the R/PA is propagating with the receiver on after set time from HOW.

Table 15.7-15. Data File 11 Definition Receiver Diagnostic Data

	Bits	LSB	Range	Units
Sync $(EDE20)_{16}$	20	NA	NA	NA
File ID = 11	4	1	15	None
Frame ID = 1	8	1	255	None
Checksum	16	NA	NA	NA
Diagnostic Data Receiver 1	352			
Diagnostic Data Receiver 2	352			
Zeros	192			
Total	944			

NOTES: 1. This file is formatted when receiver diagnostic processing is completed if the file index is greater than zero.

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Table 15.7-15. Data File 11 Definition Receiver Diagnostic Data (Cont'd)

Receiver 1	Bits	LSB	Range	Units
**Baseband AFI Warnings	16	NA	NA	NA
***Baseband AFI Failures	16	NA	NA	NA
VCO Slope	16	1	$\pm 2^{15}-1$	DAC/Chips
VCO Intercept	16	1	$\pm 2^{15}-1$	DAC
VCO Linearity Error Count	8	1	63	Errors
Linearity offset	16	*	*	Chips
L1-P Control Loop Configuration	8	NA	NA	NA
L1-P Frequency Drift	16	*	*	Chips
L1-C/A Control Loop Configuration	8	NA	NA	NA
L1-C/A Frequency Drift	16	*	*	Chips
L2-P Control Loop Configuration	8	NA	NA	NA
L2-P Frequency Drift	16	*	*	Chips
L1-P Search Rate Configuration	8	NA	NA	NA
L1-P Dismiss Rate	16	1	$\pm 2^{15}-1$	CT Epochs
L1-C/A Search Rate Configuration	8	NA	NA	NA
L1-C/A Dismiss Rate	16	1	$\pm 2^{15}-1$	CT Epochs
L2-P Search Rate Configuration	8	NA	NA	NA
L2-P Dismiss Rate	16	1	$\pm 2^{15}-1$	CT Epochs
Slew Error	16	*	*	Chips
1-ms Data Demodulation	8	NA	NA	NA
20-ms Data Demodulation	8	NA	NA	NA
Signal Test-Code Sync	8	NA	NA	NA
Signal Test-Costas Lock	8	NA	NA	NA
Signal Test-Detection Time	16	1	$\pm 2^{15}-1$	CT Epochs
Signal Test L1-P Drift	16	*	*	Chips
Signal Test L2-P Drift	16	*	*	Chips
Rate Aid Configuration	8	NA	NA	NA
Rate Aid Offset	16	*	*	Chips
	352			
Receiver 2	352			

* MSB's of a single precision floating point number.

** Refer to Data File 4, Receiver Diagnostics, for definition of these 16 bits.

*** These 16 bits are used to report failures for the same tests as the above defined warnings, except for tests 2, 3, 4, and 5 which have no failure threshold.

16.0 DIRECT ACCESS S-BAND

16.0 DASB

SECTION 16.0

DIRECT ACCESS S-BAND

The Direct Access S-Band (DASB) subsystem consists of two S-Band transmitters, a coaxial switching unit and an S-Band shaped beam antenna. Subsystem inputs are clock signals, multiplexed MSS data and command signals. Subsystem outputs consist of RF signals and telemetry.

16.1 FUNCTIONAL DESCRIPTION

The direct access S-band transmitter receives a 15.06 Mbps NRZ-L digital data and clock signals from the MSS. The data is reclocked, voltage limited, low-pass filtered, then used to frequency modulate (continuous-phase PCM-FM) one of the command selectable, redundant 10 watt 2265.5 MHz transmitters. A block diagram of the Direct Access S-band subsystem is shown in Figure 16.1-1.

16.2 PERFORMANCE CAPABILITIES

Output Performance

Center Frequency:2265.5 MHz
Center Frequency Stability:±0.005%
Output Power:10 Watts, minimum

Modulation Characteristics

Type Data:NRZ-L PCM-FM
Deviation±5.6 MHz ±5%
Deviation Sense:Positive for Logic "1"
Modulation Data Format:15.06 Mbps NRZ-L
Modulation Transition Time: 35 nanoseconds (10% to 90%)

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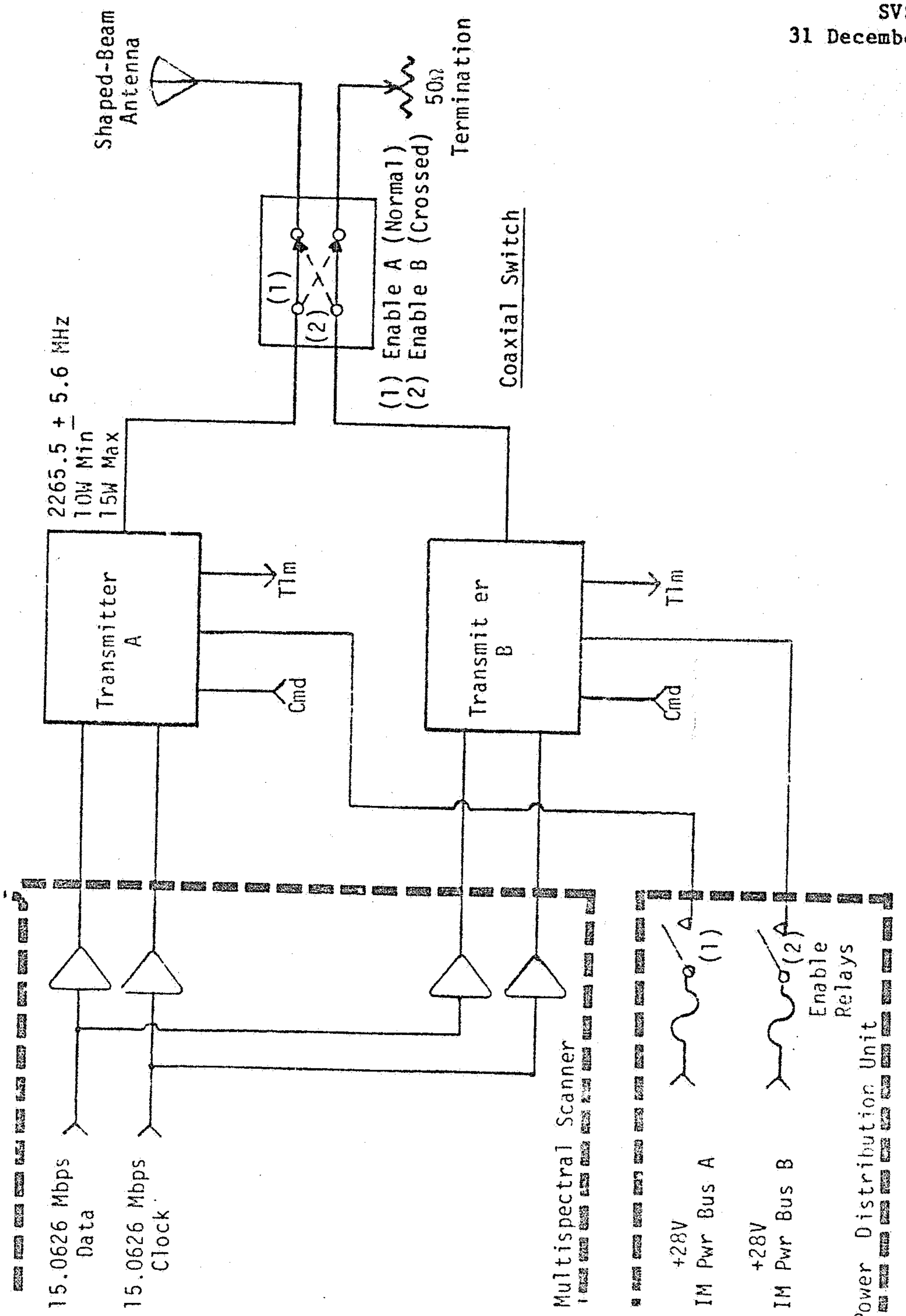

Figure 16.1-1. Direct Access S-Band Block Diagram

16.3 MODES OF OPERATION

There are only ON or OFF operating modes for the transmitters as shown in Table 16.3-1.

Table 16.3-1. S-Band Operating Modes

	XMTR A	XMTR B
MODE A	ON	OFF
MODE B	OFF	ON
MODE C	OFF	OFF

NOTE: Prime power for S-Band transmitter operation is provided via the Power Distribution Unit (PDU). The power enable commands also select the coaxial switch configuration for routing the selected transmitter's power output to the S-band shaped beam antenna.

16.4 CONSTRAINTS

The operating constraints for the direct readout S-band transmitters are as follows:

1. Only one transmitter should be powered at a time.

2. The transmitters will be off during launch, and transmission can commence 8 hours after launch.

3. The maximum duty cycle should be 30 minutes maximum in a 100 minute period. The nominal duty cycle is 15 minutes in a 100 minute period.

4. Maximum transmitter power amplifier temperature is 70°C. The OBC continuously monitors the S-band power amplifier temperature telemetry point and issues the S-band power OFF command when the last three consecutive samples of the temperature telemetry point checks out-of-limit.

5. Both transmitters should be off before issuing an enable command for a transmitter.

16.5 REDUNDANCY/CROSS STRAPPING

Redundancy is provided by two separate transmitters with either selected by individual ON and OFF commands.

Cross strapping is provided for the selected transmitter power output to the S-band antenna via the coax switch. The coax switch configuration is set with the Transmitter A Enable or the Transmitter B Enable command executed in the PDU. See Figure 16.5-1 for the location of S-band redundancies.

16.6 COMMANDS

All commands for the DASB transmitters are related to supplying DC power for their operation. Seven real-time, discrete commands are used for this purpose and, of these, three are in the PDU while the remaining four are in the DASB transmitters. All of these commands are listed in Table 16.6-1.

The commands effected through the PDU are described in Paragraph 16.6.1 which also includes illustrative circuitry. Similar information on the commands in the DASB transmitters is provided in Paragraph 16.6.2.

16.6.1 COMMANDS VIA THE PDU

The commands for the DASB which are implemented in the PDU are identified by command name and Remote Interface Unit (RIU) channel number in Table 16.6-1. The block diagrams for these circuits is provided in Figure 16.6-1.

16.6.1.1 Transmitter A Power Enable (FNSBDA, Cmd 604)

This command employs pulse stretching circuitry to close the bipolar relay which channels fused 28 Vdc power from Instrument Module (IM) Bus A in the PDU to the power supply of Transmitter A of the DASB subsystem as shown in Figure 16.6-1. Note that closure of this relay results in supplying charging currents to any input filter elements of Transmitter A (including those of the dc/dc converter, if connected). Therefore, to minimize the energy that must be supplied through the contacts of the Power Enable relay to charge input filters, the transmitter should be deenergized whenever possible by sending the Transmitter A Power Off (SAOFF) command (see Paragraph 16.6.2.2 for information on this command) rather than by the use of the Disable command.

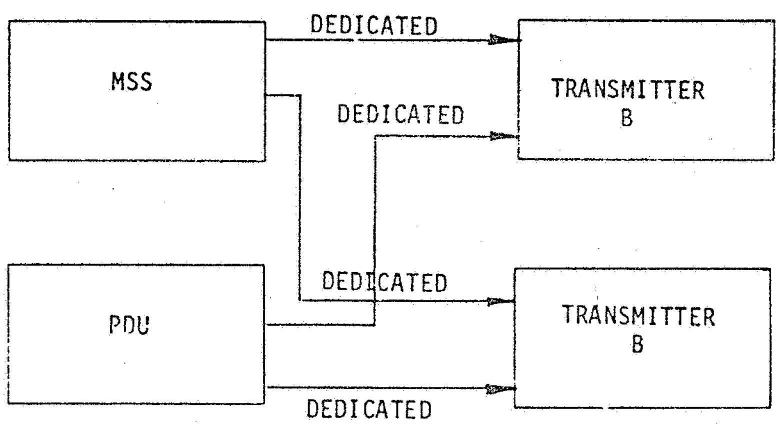

Figure 16.5-1. Direct Access S-Band Redundancies

Table 16.6-1. Direct Access S-Band Transmitter Command List

Command Name	Acronym	RIU-CH.	Subsystem	Reference Paragraph
XMTR A PWR ENABLE	ENSBDA	6-04	PDU	16.6.1.1
XMTR B PWR ENABLE	ENSBDB	6-08	PDU	16.6.1.2
XMTR PWR DISABLE	DISSBD	6-35	PDU	16.6.1.3
XMTR A PWR ON	SAON	8-02	DASB	16.6.2.1
XMTR A PWR OFF	SAOFF	8-53	DASB	16.6.2.2
XMTR B PWR ON	SBON	8-57	DASB	16.6.2.3
XMTR B PWR OFF	SBOFF	8-30	DASB	16.6.2.4

In addition to enabling this power source, this command is also routed to the pulse stretcher which controls the bipolar relay of the Coaxial Switch. The Transmitter A Power Enable command orients the coaxial elements of this switch so that the RF output of Transmitter A is connected to the shaped-beam S-Band antenna when power is supplied to Transmitter A. Note that while IM Bus A (28 Vdc) powers the Transmitter A Enable relay coil and Transmitter A of the DASB, the coaxial relay coils are energized from either Bus A or Bus B, utilizing diodes to maintain isolation of these two busses and 1/4 A fuses to provide bus protection.

16.6.1.2 Transmitter B Power Enable (ENSBDB, Cmd 608)

Fused power from IM Bus B in the PDU Transmitter B of the DASB is enabled by this bipolar relay using circuitry identical to that for Transmitter A as illustrated in Figure 16.6-1. Again, to protect the contacts of this relay, Transmitter B should be deenergized whenever possible by the Transmitter B Power Off (SBOFF) command (see Paragraph 16.6.2.4 for information on this command) rather than by the use of the Disable command. The Transmitter B Power Enable command also actuates the coil of the Coaxial Switch relay so that its elements route the RF output of Transmitter B to the shaped-beam S-band antenna when this transmitter is energized. This coil of the Coaxial Switch is provided power in a manner similar to that described in Paragraph 16.6.1.1.

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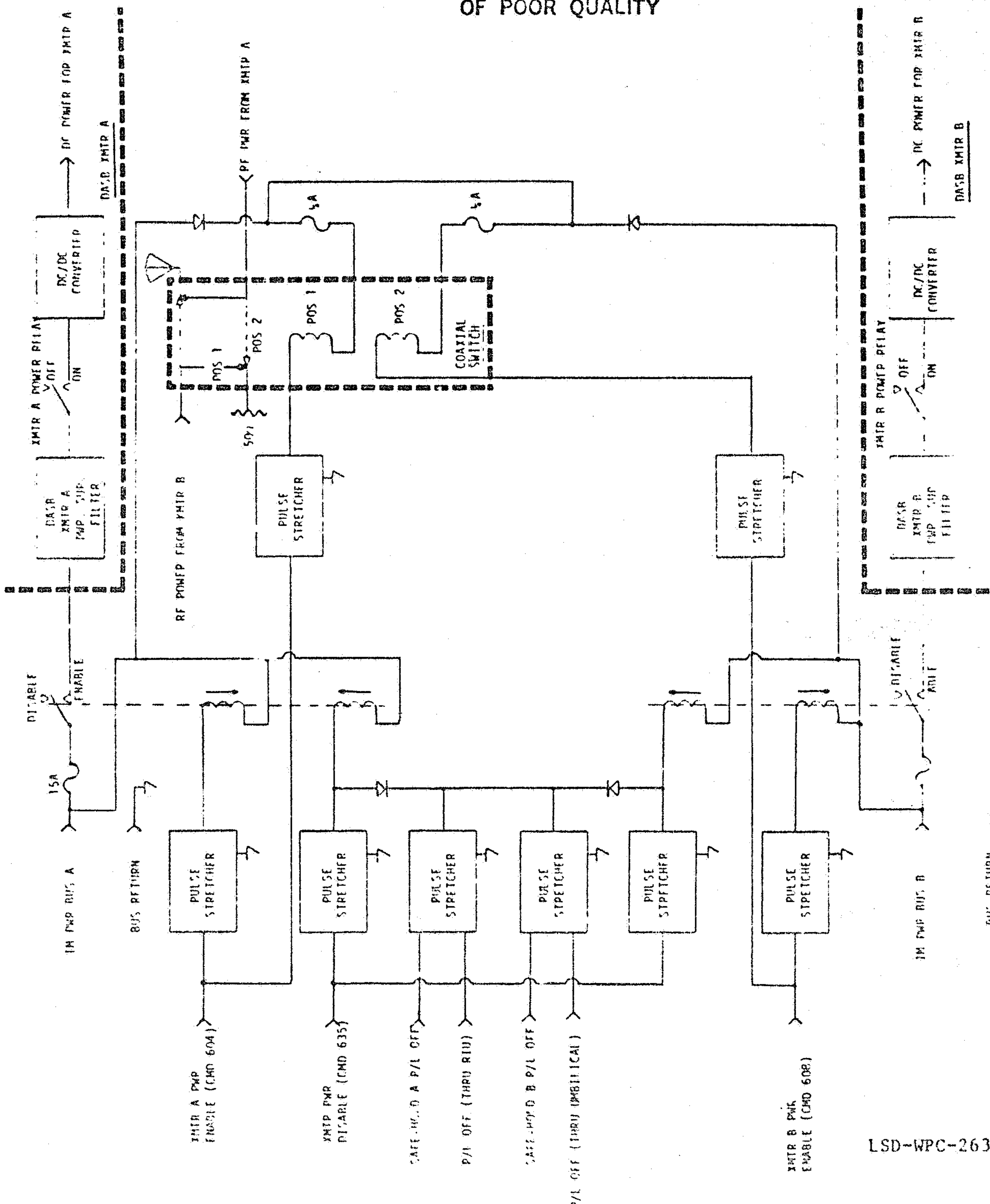

Figure 16.6-1. Circuitry of DASB Commands Included in the PDU

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16.6.1.3 Transmitter Power Disable (DISSBD, Cmd 635)

This command is mechanized to remove the dc power from both transmitters and thus to turn them off. As depicted in Figure 16.6-1, the command pulse is applied to pulse stretchers servicing the disable coils for the enabling relays of both transmitters.

In addition to being disabled by this specific command, these relays are also inactivated by four other means. The PDU develops redundant Payload Off signals whenever it receives an indication from the Modular Attitude Control System (MACS) of the Flight Segment (FS) that the Safe-Hold (S/H) mode of attitude control has been implemented. These redundant signals (S/H A and S/H B) are applied to separate pulse stretchers in the PDU which are connected through diodes to operate the disable coils for the enabling relays of both transmitters. In addition, when a Payload Off command is received by the PDU from its RIU, this signal is provided in a logical "or" arrangment with the S/H A signal to the appropriate pulse stretcher. A similar Payload Off command received by means of an umbilical connection from either the Shuttle or launch site blockhouse can be accepted by the pulse stretcher associated with the S/H B signal.

In summary, power to both transmitters will be interrupted when any one of these five signals are received and/or processed by the PDU:

1. Transmitter Disable Command

2. Safe-Hold A activation

3. Safe-Hold B activation

4. Payloads Off command through the RIU supervisory line

5. Payloads Off command through the umbilical connection.

16.6.2 COMMANDS IN THE DASB TRANSMITTERS

Those commands which are in the DASB transmitters are identified in Table 16.6-1 by command name and RIU channel number. The block diagram for the command circuitry is provided in Figure 16.6-2.

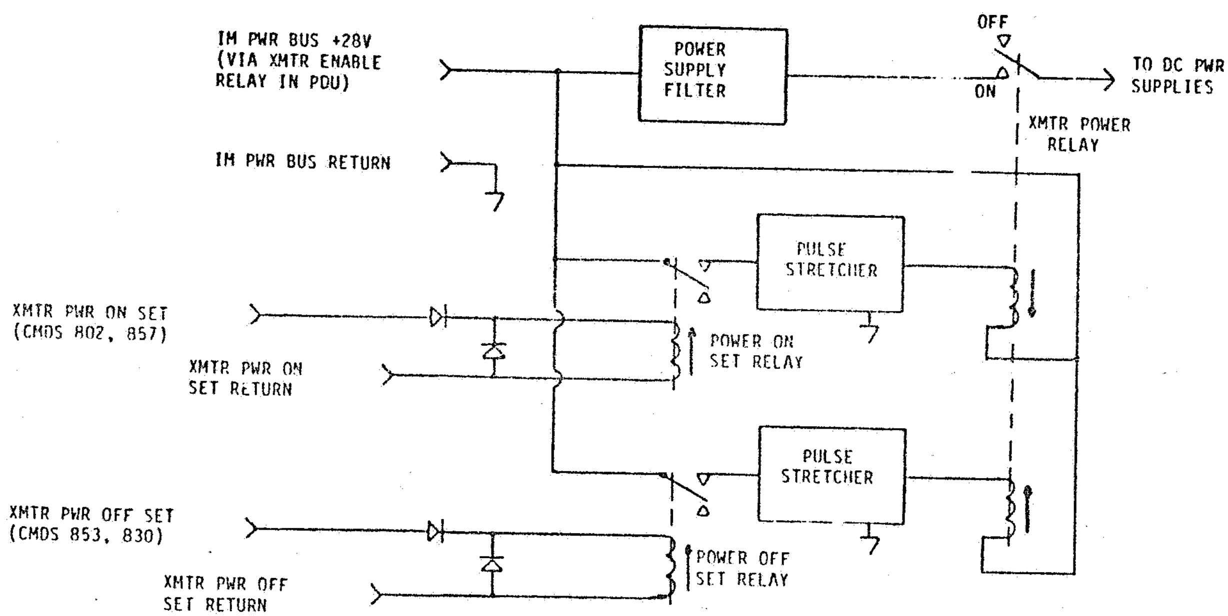

Figure 16.6-2. Block Diagram of DASB Command Circuits

16.6.2.1 Transmitter A Power On (SAON, Cmd 802)

This discrete pulse command is applied to the Transmitter A Power On Set relay, the contacts of which supply a 28 Vdc signal to a pulse stretcher that activates the "On" coil of the bipolar Transmitter A Power Relay, as illustrated in Figure 16.6-2. A review of this circuit and that of Figure 16.6-1 will indicate that this relay cannot be actuated until 28 Vdc is present as the result of closing the Transmitter A Enable relay. The 28 Vdc is used both in the pulse stretcher circuit and to energize the relay coil.

16.6.2.2 Transmitter A Power Off (SAOFF, CMd 853)

This command is implemented through the same type of circuitry as that described in Paragraph 16.6.2.1 (and shown in Figure 16.6-2) to remove the 28 Vdc from this transmitter and thus to deenergize it. As mentioned in Paragraph 16.6.1.1, the normal mode of removing this transmitter from operation should always be by means of this command. This routine will minimize the charging current flow through the enable relay contacts by normally requiring only the charging of the Power Supply Filter. Obviously, if an abnormal shut down is initiated by a Payloads Off or a Safe-Hold signal, this procedure cannot be followed.

16.6.2.3 Transmitter B Power On (SBON, Cmd 857)

The mechanization of this command is the same as that for Transmitter A Power On described in Paragraph 16.6.2.1 except that the B unit is operated.

16.6.2.4 Transmitter B Power Off (SBOFF, Cmd 830)

The description of this command's operation is the same as that for the Transmitter A Power Off (Paragraph 16.6.2.2) except that Transmitter B is affected.

16.6.3 COMMAND SEQUENCES

The sequence of commands for functions associated with the DASB are listed in Table 16.6-2.

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Table 16.6-2. DASB Command Sequences

FUNCTION	STEP NO.	COMMAND NAME	ACRONYM
Turn Transmitter A On	1	XMTR A PWR ENABLE*	ENSBDA
	2	XMTR A PWR ON	SAON
Turn Transmitter A Off (Normal)	1	XMTR A PWR OFF	SAOFF
Turn Transmitter B On	1	XMTR B PWR ENABLE*	ENSBDB
	2	XMTR B PWR ON	SBON
Turn Transmitter B Off (Normal)	1	XMTR B PWR OFF	SBOFF

NOTE: In the event that the transmitter in use has failed and it is desired to place the other transmitter in operation, the "Turn Transmitter Off" command for the transmitter to be removed from service should be followed by "Transmitter Power Disable" command.

* The Enable command associated with the specific transmitter should always be sent before its Power On command is sent since the Enable command also commits the S-band antenna to the transmitter enabled. This precaution will assure that the transmitter in use is connected to the transmitting antenna.

16.7 TELEMETRY

Operation of the DASB transmitter is monitored by using a total of 15 telemetry channels. Eleven of these are in the transmitter itself and of these, three are bi-level digital, six are active analog and two are passive analog. Two bi-level digital monitors are in the PDU and two analog telemetry points are included in the thermal subsystem monitors. All of these telemetry monitor channels are listed in Table 16.7-1. The monitors in the DASB are described and circuitry illustrated in Paragraphs 16.7.1 through 16.7.3. Similar information on telemetry monitors in other subsystems is provided in Paragraph 16.7.4.

16.7.1 DASB DIGITAL BI-LEVEL WORD TELEMETRY MONITORS

The functions in the DASB that are monitored by bi-level digital words are listed in Table 16.7-1 by their user identification (ID) number. As indicated there, these monitors are included in Bi-level Word 707. Table 16.7-2 provides the details of these telemetry data.

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Table 16.7-1. Direct Access S-Band Transmitter Telemetry List

USER ID	FUNCTION NAME	ACRONYM	SIGNAL TYPE	MATRIX LOCATION COL., ROW MISSION	ENG'G	RIU-CH	REFERENCE PARAGRAPH
DASB-01	BILEVEL WORD 707:					07-72	
Bit 0	XMTR A POWER ON/OFF (RELAY ONLY)	SXMTRAON	B/L-D	33,76	33,76	07-72	16.7.1.1
Bit 1	XMTR B POWER ON/OFF (RELAY ONLY)	SXMTRBON	B/L-D	33,76	33,76	07-73	16.7.1.2
Bit 4	S-B ANTENNA SELECT XMTRA/XMTR B	SANTAORB	B/L-D	33,76	33,76	07-76	16.7.1.3
DASB-02	XMTR A POWER SUPPLY MONITOR	SAPWRSUP	Act-An	33,77	33,77	07-96	16.7.2.1
DASB-03	XMTR B POWER SUPPLY MONITOR	SBPWRSUP	Act-An	33,78	33,78	07-97	16.7.2.2
DASB-06	XMTR A FORWARD RF POWER	SAFWDPWR	Act-An	33,81	33,81	07-98	16.7.2.3
DASB-07	XMTR B FORWARD RF POWER	SBFWDPWR	Act-An	33,82	33,82	07-99	16.7.2.4
DASB-08	XMTR A REFLECTED RF POWER	SAREFPWR	Act-An	33,83	33,83	07-100	16.7.2.5
DASB-09	XMTR B REFLECTED RF POWER	SBREFPWR	Act-An	33,84	33,84	07-101	16.7.2.6
DASB-04	XMTR A POWER AMP TEMP	SAPAT	Pas-An	33,79	33,79	07-18	16.7.3.1
DASB-05	XMTR B POWER AMP TEMP	SBPAT	Pas-An	33,80	33,80	07-19	16.7.3.2
PDU-02	BI-LEVEL WORD 601:						
Bit 6	DASB POWER A ENABLED/DISABLED	YSBAPWR	B/L-D	33,85	33,85	06-47	16.7.4.1.1
Bit 7	DASB POWER B ENABLED/DISABLED	YSBBPWR	B/L-D	33,86	33,86	06-48	16.7.4.1.2
TH-19	S-BAND XMTR PANEL TEMP NO. 1	QTSBXP1	Pas-An	33,103	33,103	07-20	16.7.4.2.1
TH-20	S-BAND XMTR PANEL TEMP NO. 2	QTSBXP2	Pas-An	33,122	33,122	08-84	16.7.4.2.2

Table 16.7-2. DASB Digital Telemetry Bits

User ID	Bit Number	Bit State	Status Indication
DASB-01 (Bi-level Word 707)	0	0	Transmitter A relay Off
		1	Transmitter A relay On and input power present
	1	0	Transmitter B relay Off
		1	Transmitter B relay On and input power present
	4	0	S-Band Antenna to Transmitter A
		1	S-Band Antenna to Transmitter B
PDU-02 (Bi-level Word 601)	6	0	Power to DASB Transmitter A Enabled
		1	Power to DASB Transmitter A Disabled
	7	0	Power to DASB Transmitter B Enabled
		1	Power to DASB Transmitter B Disabled

16.7.1.1 <u>Transmitter A Power On/Off (DASB-01, Bit 0)</u>

The status of the power relay for Transmitter A of the DASB is indicated by this monitor in accordance with the bit states identified in Table 16.7-2. The monitor utilizes 28 Vdc power from the PDU through the "DASB Enable Power A" relay in that unit (see Paragraph 16.7.4.1.1). For this reason the monitor of this relay status has no meaning unless Transmitter A has been enabled in the PDU. The circuitry associated with this telemetry point is shown near the Transmitter A Power On/Off relay in Figure 16.7-1.

16.7.1.2 <u>Transmitter B Power On/Off (DASB-01, Bit 1)</u>

The status of the power relay for Transmitter B of the DASB is indicated by this monitor in accordance with the bit states identified in Table 16.7-2. The circuitry is shown in Figure 16.7-2 with 28 Vdc power being supplied from the PDU through the "DASB Enable Power B" relay (see Paragraph 16.7.4.1.2). The monitor of this relay status has no meaning unless Transmitter B has been enabled in the PDU.

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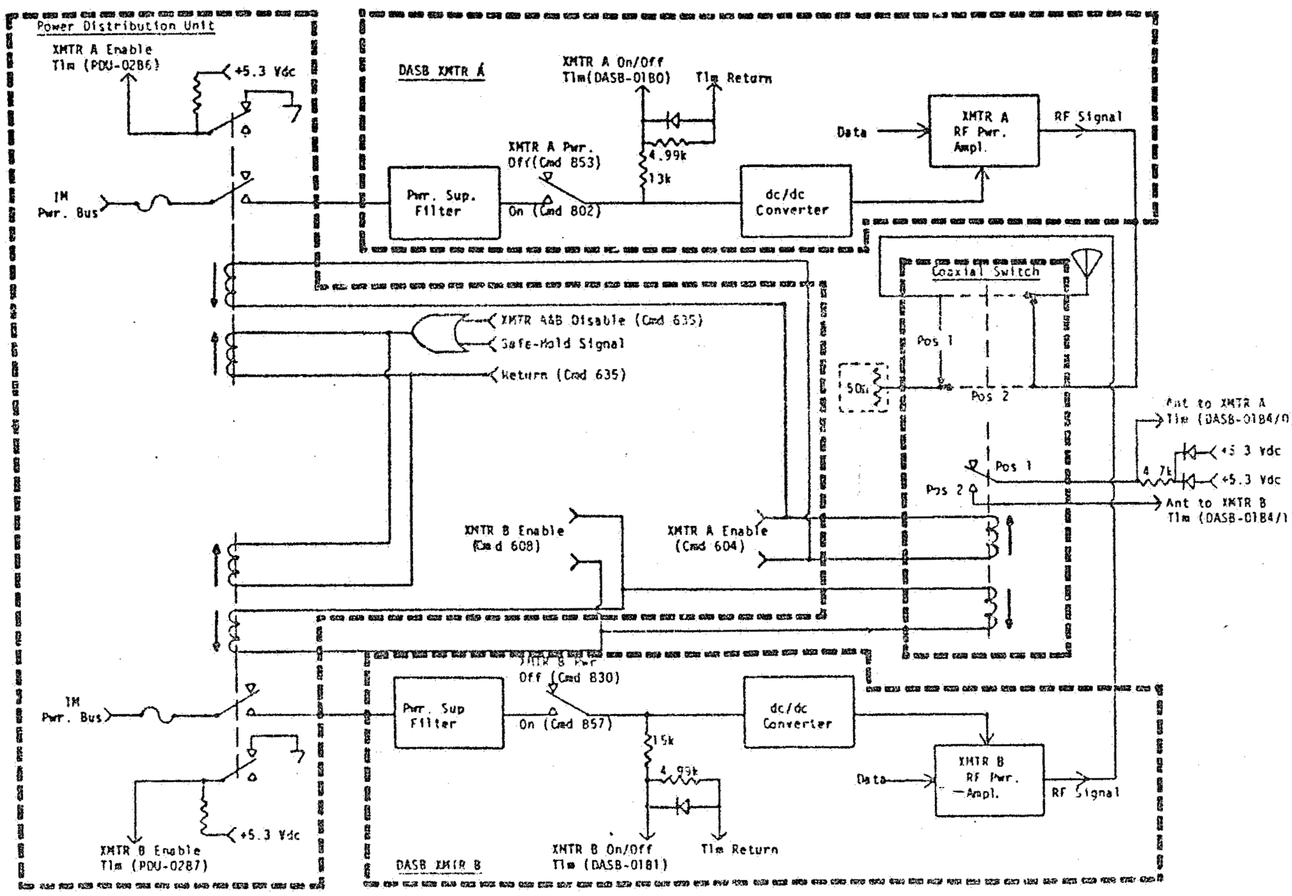

Figure 16.7-1. Interrelated DASB Telemetr, circuitry

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16.7.1.3 S-Band Antenna Select Transmitter A/Transmitter B (DASB-01, Bit 4)

The identification of the transmitter which is connected to the S-band antenna is provided by this monitor in accordance with the bit states shown in Table 16.7-2. This telemetry is energized by the power supply in RIU 7A/7B utilizing the circuitry associated with the Coaxial Switch on Figure 16.7-1.

16.7.2 DASB ACTIVE ANALOG TELEMETRY MONITORS

The analog telemetry monitors for the DASB are listed in Table 16.7-1 by their user ID number and function names. Telemetry limits are defined in Table 16.7-3. For information regarding calibration curves for the telemetered functions, see Appendix A.16.

16.7.2.1 Transmitter A Power Supply (DASB-02)

The level of voltage from the pre-regulated, +23 Vdc power supply for Transmitter A is measured by a voltage divider connected between the supply and its return line. This supply is used in the RF amplifier and output circuitry for the A transmitter. Since its level is only pre-regulated, it serves as an indicator for the health of the DC to DC converter and the power to the +18V, ±15V and ±5 Vdc power supply outputs for the A transmitter, all of which are regulated sources. The circuit for this monitor is shown in Figure 16.7-2. Operating limits for this function are listed in Table 16.7-3 and the calibration curve is shown in Figure A16-1.

16.7.2.2 Transmitter B Power Supply (DASB-03)

The description of this telemetry function is identical to that in Paragraph 16.7.2.1 except that the power supply of DSAB Transmitter B is monitored.

16.7.2.3 Transmitter A Forward RF Power (DASB-06)

This telemetry function monitors the level of power which is sent from the RF amplifier of DASB Transmitter A to the antenna. Elements in a circulator isolator filter are used as the means to develop a DC voltage across a resistor that is proportional to the RF output of the power amplifier for this transmitter. The circuit for the monitor is shown in Figure 16.7-3. Operating limits are listed in Table 16.7-3.

Table 16.7-3. Direct Access S-Band Transmitter Limits

USER ID	ACRONYM	MODE	Lower #		Upper #		ENG. UNITS
			Red	Yel	Yel	Red	
DASB-02	SADPWRSUP	Transmitter A On	21.8	22.4	23.6	24.2	Volts
DASB-03	SBPWRSUP	Transmitter B On	21.8	22.4	23.6	24.2	Volts
DASB-06	SAFWDPWR	Transmitter A On	10	11	14	15	Watts
DASB-07	SBFWDPWR	Transmitter B On	10	11	14	15	Watts
DASB-08	SAREFPWR	Transmitter A On	0	0	0.5	0.6	Watts
DASB-09	SBREFPWR	Transmitter B On	0	0	0.5	0.6	Watts
DASB-04	SAPAT	Transmitter A On	(0)*	10	55	(70)*	°C
DASB-05	SBPAT	Transmitter B On	(0)*	10	55	(70)*	°C
TH-19	QTSBXP1	Transmitter A or B On	(0)*	10	40	(55)*	°C
TH-20	QTSBXP2	Transmitter A or B On	(0)*	10	40	(55)*	°C

The Yellow limits are those at which warnings should be given. The Red Limits are the values which are not to be exceeded.

* While the expected orbital maximum temperature values are shown as upper Yellow limits, the subsystem has been subjected to the parenthetical values (Red limits) during subsystem qualification testing.

16.7.2.4 Transmitter B Forward Power (DASB-07)

The description of this telemetry function is identical to that in Paragraph 16.7.2.3 except that the RF forward power from the DASB Transmitter B is monitored.

16.7.2.5 Transmitter A Reflected RF Power (DASB-08)

The power reflected back from the transmission line and antenna to DASB Transmitter A is monitored by this telemetry circuit. Another part of the same circular isolator filter used for forward power monitoring is utilized for this telemetry monitor. The Voltage Standing Wave Ratio (VSWR) at the transmitter may be calculated from the forward and reflected power data obtained by using this formula:

$$\text{VSWR} = \frac{1 +}{1 -}$$

$$\text{where } {}^{2} = \frac{\text{Reflected RF Power}}{\text{Forward RF Power}}$$

The elements of the filter and the circuit used to develop the telemetry signal proportional to the reflected power are shown in Figure 16.7-3. Operating limits are listed in Table 16.7-3.

16.7.2.6 Transmitter B Reflected RF Power (DASB-09)

The description of this telemetry function is identical to that in Paragraph 16.7.2.5 except that the reflected RF power with the DASB Transmitter B antenna system is monitored.

16.7.3 DASB PASSIVE ANALOG TELEMETRY MONITORS

The passive analog telemetry monitors for the DASB are listed in Table 16.7-1 by User ID number and function name. Telemetry limits are defined in Table 16.7-3. For information regarding calibration data for the telemetry functions, see Appendix A.16.

16.7.3.1 Transmitter A Power Amplifier Temperature (DASB-04)

The temperature of the power amplifier of the DASB Transmitter A is monitored by this telemetry point. The circuitry for this passive analog circuit is shown in Figure 16.7-4. The 1 mA current pulse for the monitor is supplied from RIU 7. Operating limits are listed in Table 16.7-2.

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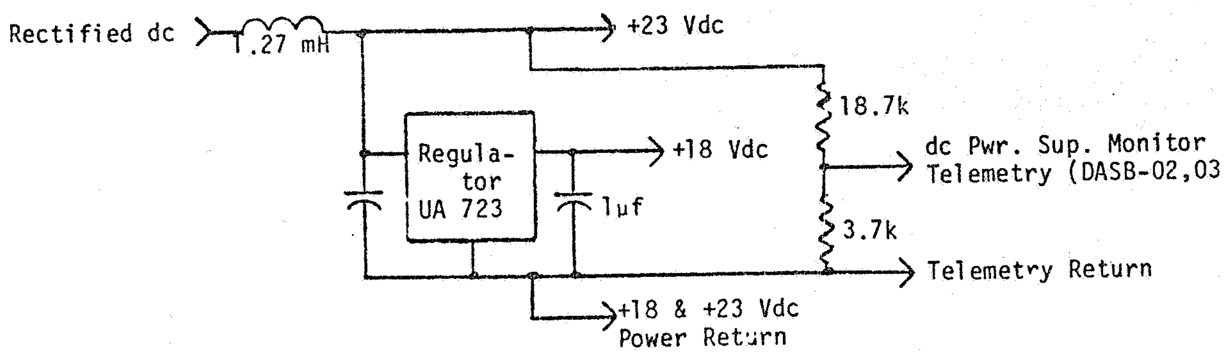

Figure 16.7-2. Transmitter Power Supply Monitor Telemetry Circuit

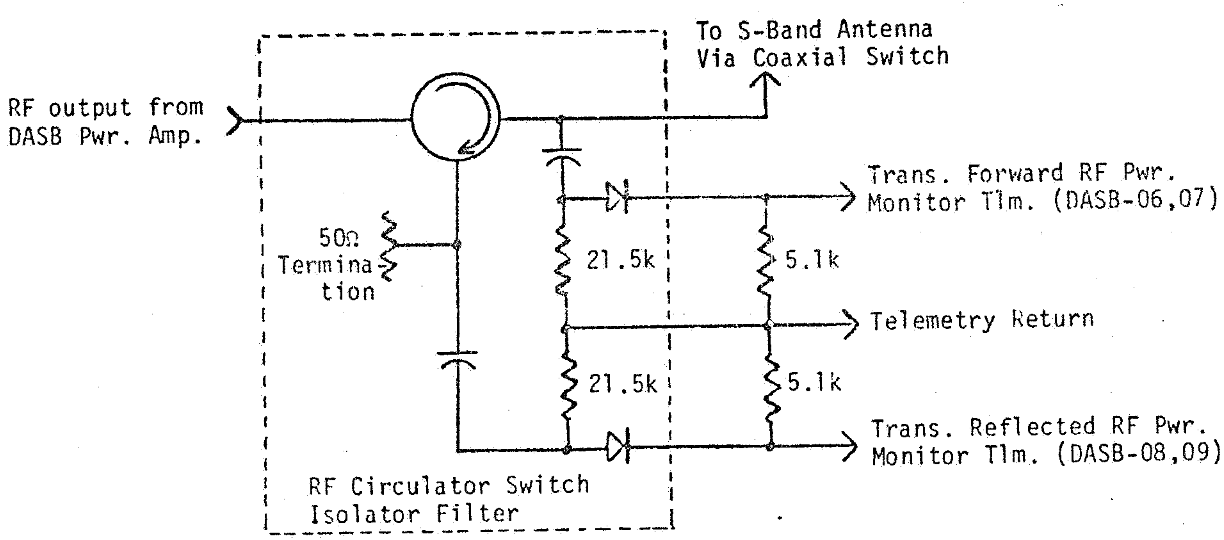

Figure 16.7-3. Transmitter RF Power Monitor Telemetry Circuit

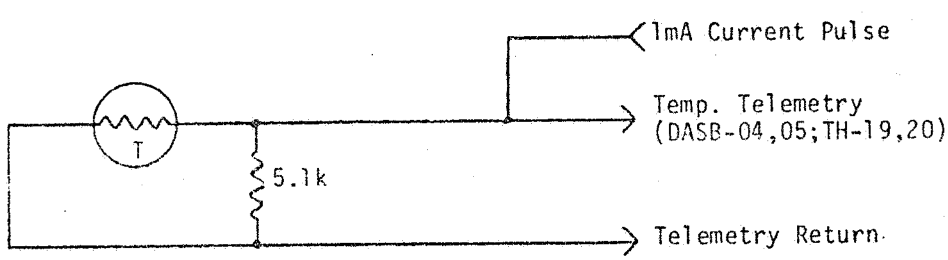

Figure 16.7-4. Transmitter Temperature Telemetry Circuit

16.7.3.2 Transmitter B Power Amplifier Temperature (DASB-05)

The description of this telemetry function is identical to that contained in Paragraph 16.7.3.1 except that the temperature is monitored in DASB Transmitter B.

16.7.4 DASB TELEMETRY IN OTHER SUBSYSTEMS

In addition to the telemetry circuits which are an integral part of the DASB, monitors for this transmitter are located in two other subsystems of the IM. Information on them is included in Tables 16.7-1 through 16.7-3, as appropriate. Descriptions of their functions and circuit illustrations are provided here.

16.7.4.1 Monitors in PDU

16.7.4.1.1 Power to DASB Transmitter A Enable/Disable (PDU-02, Bit 6)

The status of the relay which provides 24 Vdc power from the IM to DASB Transmitter A is monitored by this bi-level digital telemetry point. Its characteristics are summarized in Table 16.7-1 and the circuitry is shown in Figure 16.7-1. The Enable relay will be disabled either by specific commands to the PDU or when the PDU receives signals that the Flight Segment must be configured for the Safe-Hold Mode as discussed in Paragraph 16.6.1.3. Any one of these conditions places the Enable/Disable relay for both Transmitters A and B in the Disable state as illustrated in Figure 16.7-1. The status indication associated with the two states of the bi-level telemetry monitor is shown in Table 16.7-2.

16.7.4.1.2 Power to DASB Transmitter B Enable/Disable (PDU-02, Bit 7)

The status of the relay which provides 24 Vdc power from the IM to DASB Transmitter B is monitored by this bi-level digital telemetry point. The description provided in Paragraph 16.7.4.1.1 applies to this monitor except that Transmitter B is affected. Note that the same functions which disable Transmitter A also disable Transmitter B.

16.7.4.2.1 S-Band Transmitter Panel Temperature No. 1 (TH-19)

The temperature at one point on the mounting panel for the S-band transmitter in the IM is monitored by this telemetry monitor. The circuitry for this passive analog circuit is shown in Figure 16.7-4. The 1 mA current pulse is supplied from RIU 7. Operating limits are listed in Table 16.7-2.

16.7.4.2.2 S-Band Transmitter Panel Temperature No. 2 (TH-20)

This monitor is a redundant unit to that described in Paragraph 16.7.4.2.1 and monitors another point on the mounting panel. Other information in that paragraph applies to this telemetry point except that the 1 mA current pulse is supplied from RIU 8.

17.0 MULTISPECTRAL SCANNER

SECTION 17.0

MULTI-SPECTRAL SCANNER

The MSS flight system is designed to gather multispectral measurements to identify geological, agricultural/forestry and other earth resource features. This system generates the information necessary to produce maps of radiant energy reflected in the assigned spectral bands in order to determine the spectral characteristics, within each resolution cell of the terrain beneath the flight segment. This is accomplished by imaging the data in all spectral bands simultaneously with the same optical system. The MMS consists of a scanner and a multiplexer.

17.1 FUNCTIONAL DESCRIPTION

The Multispectral Scanner (MSS) subsystem gathers data by imaging the surface of the earth in several spectral bands simultaneously through the same optical system. Figure 17.1-1 is a highly-simplified pictorial overview. Figure 17.1-2 provides the scanner functional block diagram. The MSS is a 4-band scanner operating in the solar-reflected spectral band region from 0.5 to 1.1 micrometer wave length. The four spectral bands are:

Band 1	0.5 to 0.6 micrometers (visible)
Band 2	0.6 to 0.7 micrometers (visible)
Band 3	0.7 to 0.8 micrometers (near IR)
Band 4	0.8 to 1.1 micrometers (near IR)

Bands 1 through 3 use photomultiplier tubes as detectors; Band 4 uses sili photodiodes.

Figures 17.1-3 and 17.1-4 illustrate the dynamics of the scan pattern. The MSS scans cross-track swaths of 185 kilometers width, imaging 6 scan lines across in each of the 4 spectral bands simultaneously (24 scan lines total). The object plane is scanned by means of an oscillating flat mirror between the scene and the double-reflector telescope type of optical chain. The 14.9 degree cross-track field of view is obtained as the mirror oscillates.

The instantaneous field of view of each detector subtends an earth-area square of 83 meters on a side from the nominal orbital altitude (705 KM). Field stops are formed for each line imaged during a scan, and for each spectral band, by the square input end of an optical fiber. Six of these fibers in each of the 4 bands are arranged in a 4 by 6 matrix in the focused area of the telescope.

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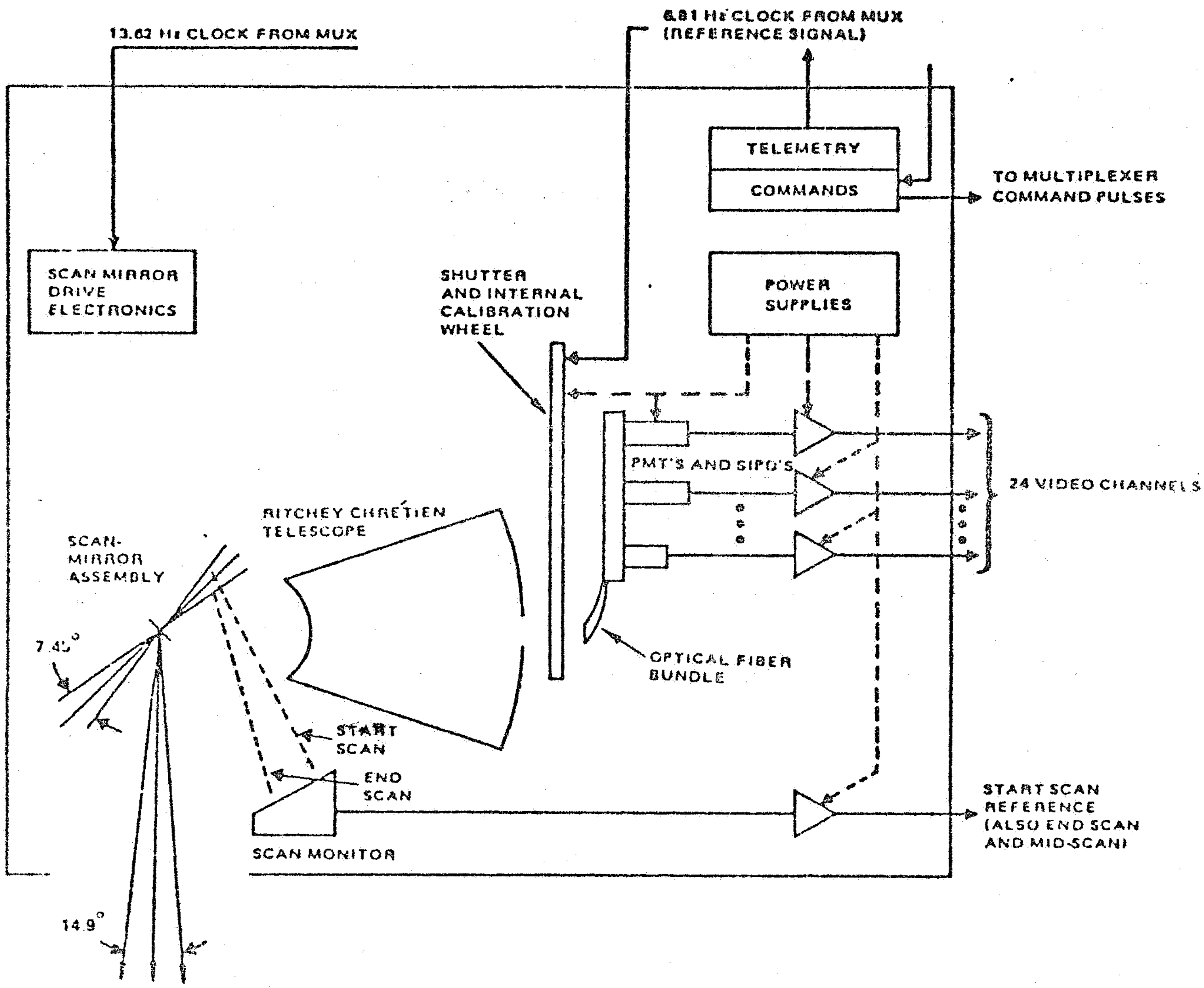

Figure 17.1-1. MSS Overview

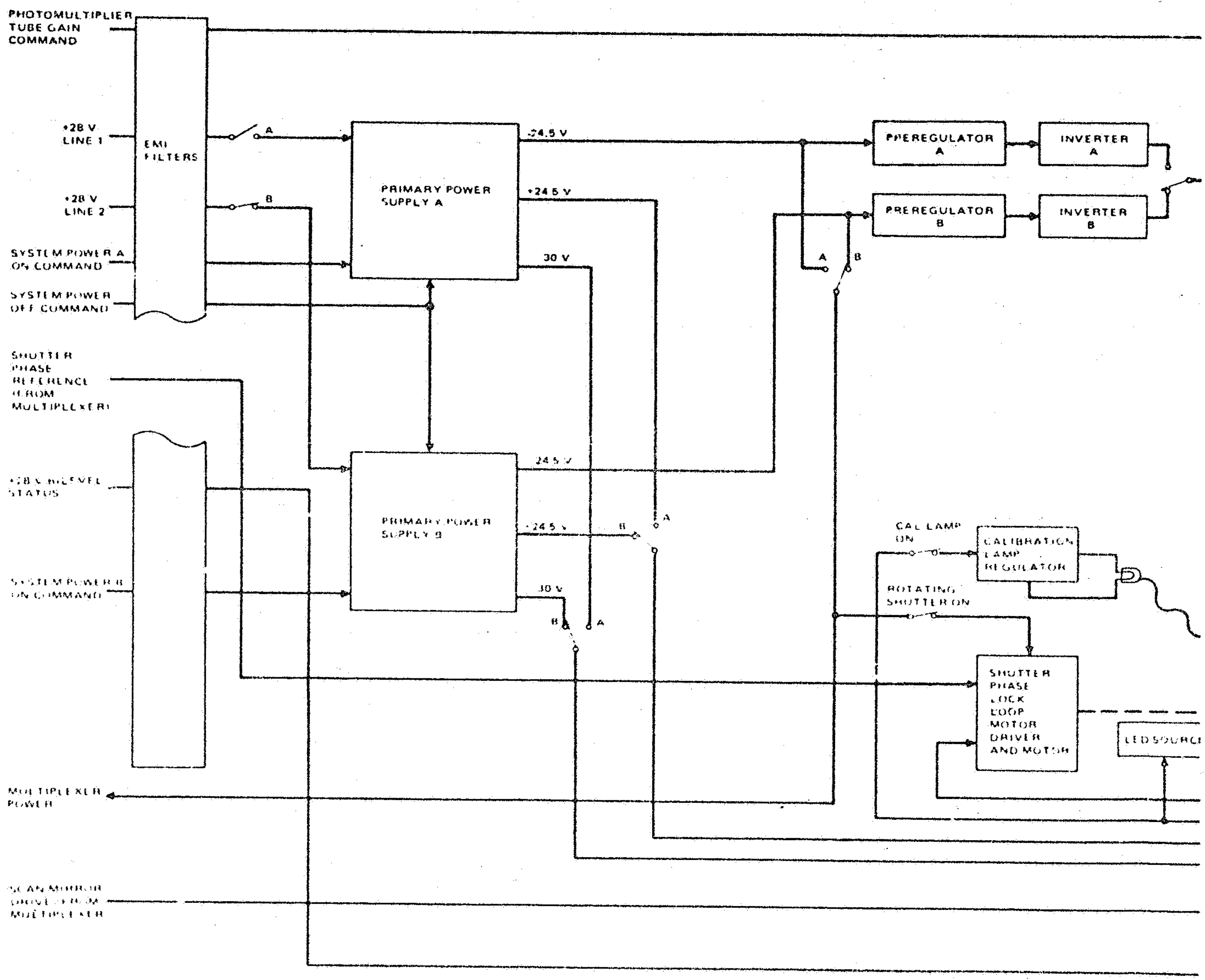

FIGURE 17 SCANNER FUNCTIONAL BLOCK DIAGRAM

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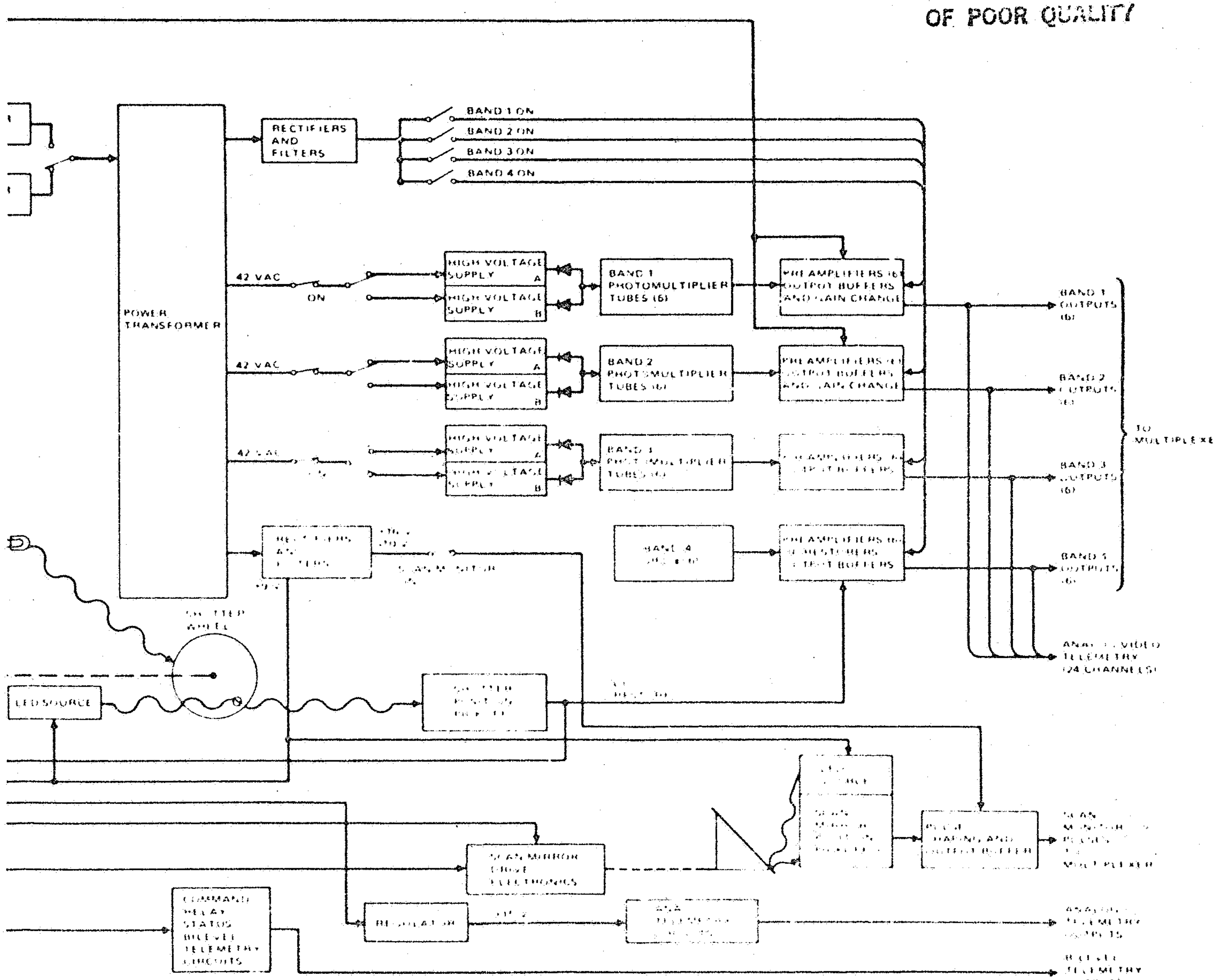

2 FOLDOUT FRAME

Figure 17.1-2. Scanner Functional Block Diagram

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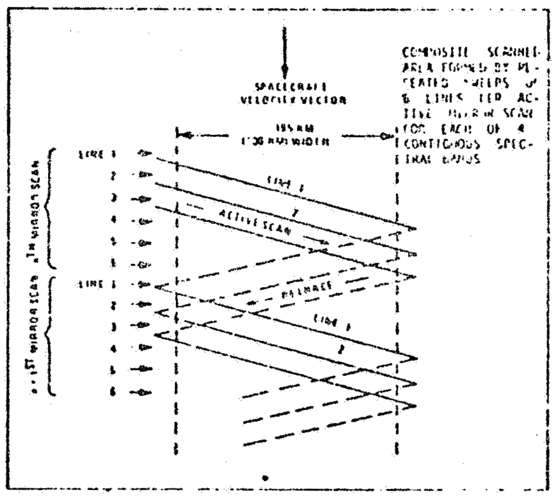

Figure 17.1-3. Ground Scan Pattern for a Single MSS Detector

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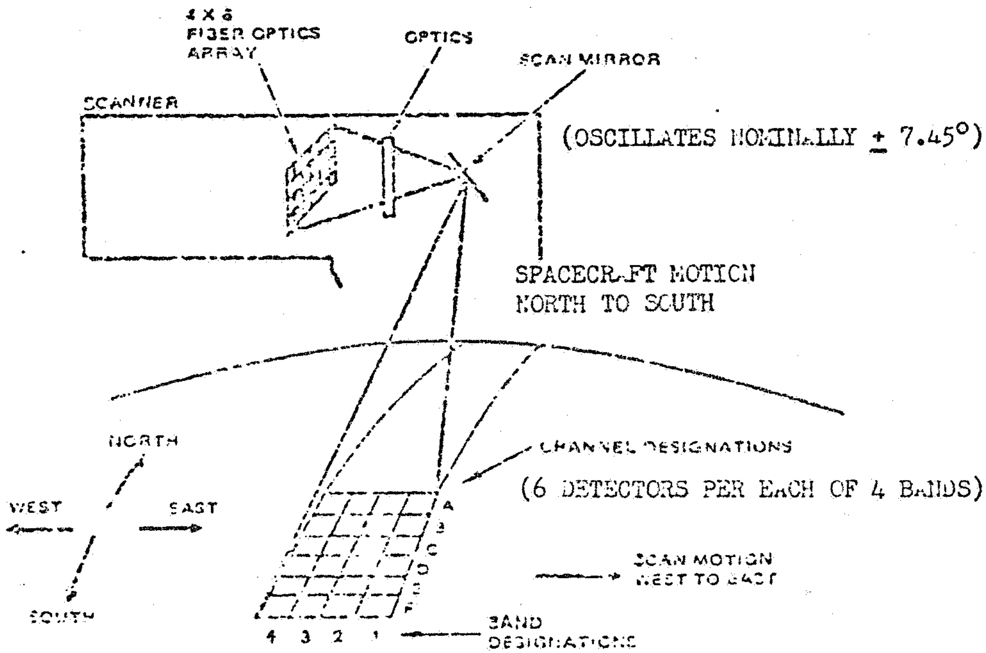

Figure 17.1-4. MSS Field Stop Pattern Projected on the Earth's Surface

LSD-WPC-263

Light impinging on each glass fiber is conducted to an individual detector through an optical filter, unique to the spectral band served. An image of a line across the swath is swept across the fiber each time the mirror scans, causing a video signal to be produced at the scanner electronics output for each of 24 channels. These signals are then sampled, digitized and formatted into a serial digital data stream by the MSS multiplexer. The signals in bands 1 and 2 can be amplified by a factor of three upon command to increase response to low level scene radiance.

The along-track scan is produced by the orbital motion of the spacecraft. The nominal orbital velocity causes an along-track motion of the subsatellite point of 6.82 km/sec neglecting spacecraft perturbation and earth rotation effects. By oscillating the mirror at a rate of 13.62 Hz, the subsatellite point will have moved 496 meters along the track during the 73.42-millisecond active scan and retrace cycle. The width of the along track field-of-view of six detectors is also 496 meters. Thus, complete coverage of the total 185 kilometer wide swath is obtained. The line scanned by the first detector in one cycle of the active mirror scan lies adjacent to the line scanned by the sixth detector of the previous mirror scan.

On-board calibration is accomplished as follows: During the retrace interval, when the scan mirror makes the transit from east to west, a shutter wheel closes off the optical fiber view to the earth and a light source is projected on the fibers via a prism. A continuously variable neutral density filter is swept across the light path so that each video channel carries a triangular pulse of about 20 milliseconds duration which begins with an abrupt transition from black to white and descends monotonically back to black. The shutter is designed to rotate once for every two scans so that the calibration signals are available during alternate retrace intervals.

17.1.1 MSS MULTIPLEXER

The MSS multiplexer provides to, or receives from, the spacecraft the signals listed below:

SIGNAL	TO/FROM
Data Signal	To spacecraft wideband and S-Band systems
Bit rate clock signal	To spacecraft wideband and S-Band systems
Time code envelope	To IM DPU
Time code strobe	To IM DPU
Time code data signal	From IM DPU

Figure 17.1-5 illustrates these functional interfaces.

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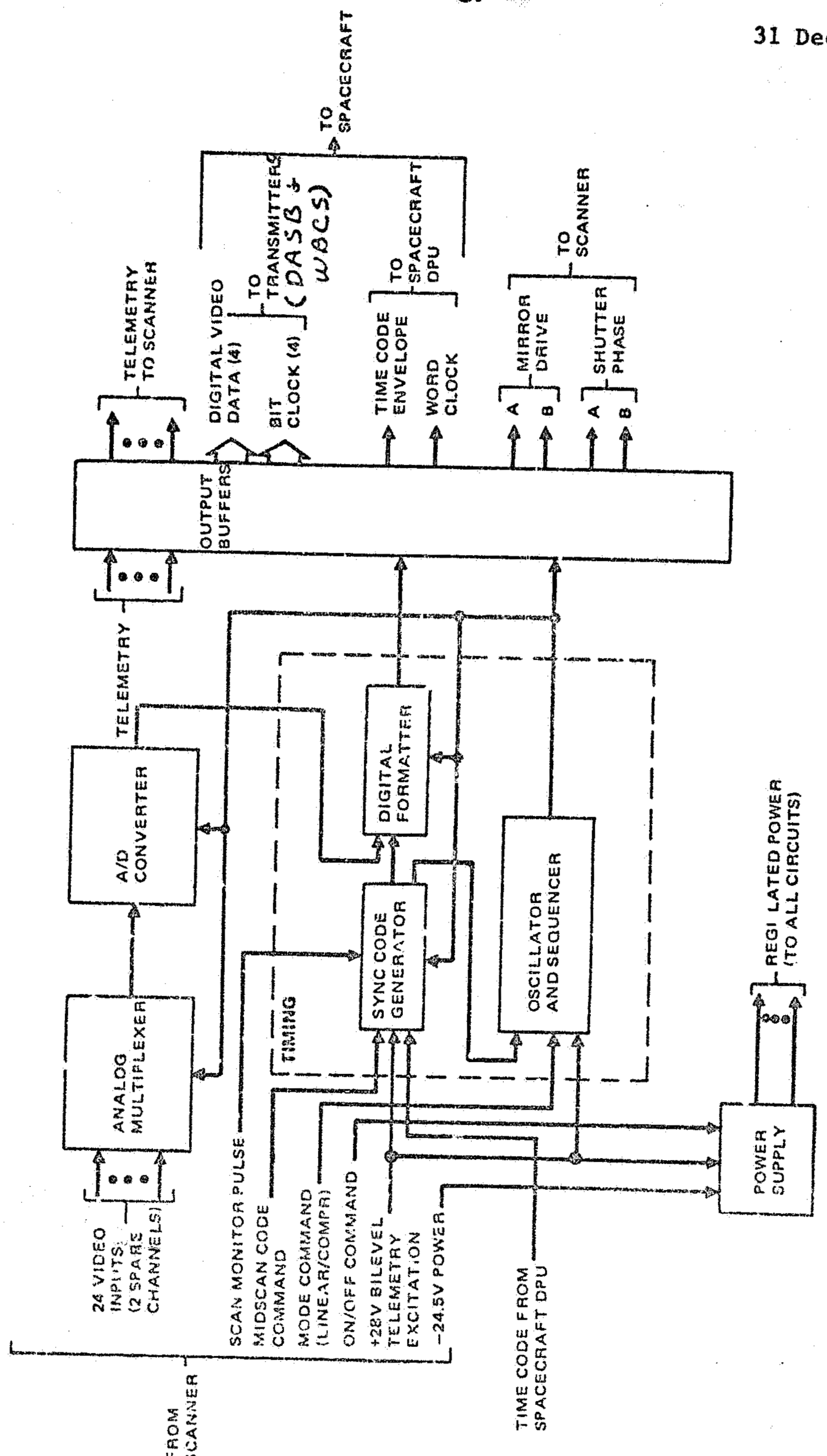

Figure 17.1-5. MSS Multiplexer Functional Block Diagram

C-5

The MSS MUX receives the analog video data from four spectral scanner bands. The data in each band represents six scan lines with calibration inputs for each complete cycle of the scan mirror. The MUX commutates each channel approximately every 10 microseconds and encodes these data into a wideband binary data bit stream. The MUX also commutates into the data bit stream, information to permit ground synchronization, including digital words identifying the start and end of the usable scan and minor frame sync code. The MUX also inserts mid scan position information upon command. The MUX interrogates a 49-bit spacecraft time code generator and commutates the returned time code data into the data bit stream. The binary data bit stream from the MUX and a bit rate clock (15 MHz) is provided to the spacecraft wideband and S-Band systems. The MUX status and diagnostic outputs are relayed to the C&DH Subsystem for output as telemetry. The MUX provides timing signals to the shutter motor, power inverter and scan mirror in the MSS scanner. The commutated samples of video in Bands 1-3 can be directed by command to either a signal compression amplifier or linear amplifier within the MUX prior to encoding. The advantage of signal compression is that it makes use of the photomultiplier tube noise characteristic to provide better resolution at low light levels than would be obtained with linear quantization. By compressing the high light levels and expanding the lower levels, a better match of the quantization noise to the detector noise is achieved. Noise levels for the silicon diode detector channels of Band 4 are established by the equivalent load resistor noise and is best matched by the linear quantization.

The scan monitor pulse, marking the start of active scan, occurs during a time when the multiplexer is iterating six bit words in a pattern termed "preamble." The arrival of the scan monitor pulse is identified by the inversion of the next word from the pattern of a preamble code. A minor frame sync code then follows and the MUX commutator is reset so that the channel for line "a" of the first band is always sampled first and the other channels next in the standard commutation pattern. This standard commutation pattern is preempted during the first sampling cycle so that the spacecraft time code may be inserted in lieu of image data. Resetting the sampling frame with the scan monitor makes the start of sampling completely angle dependent and, therefore, immune to small timing variations that could arise from the scan mechanism.

Mid scan code data can be inserted in the video data bit stream (by command) upon receipt of the middle of the scan monitor pulse from the scanner. Beginning with the word period immediately following the receipt of the pulse, the multiplexer will transmit the encoded equivalent of the black sensor level for the next 100 words then the encoded equivalent of the white sensor level for the next 100 words. In the next word period, video data will resume.

Upon receipt of the end of the scan monitor pulse from the scanner, the MUX prempts transmission of sensor data from the scanner and transmits the end of scan mode. This code is identical to the black and while level codes for patterns of the middle of scan code.

Word rate and bit rate is maintained uniformly from scan to scan and divides integrally into a scan cycle. The 13.62 Hz mirror drive signal is derived by the MUX from its master oscillator of 30 MHz. Bit and word synchronization are to be maintained continuously by the demultiplexer. Only the line start and minor frame synchronization need to be acquired in each scan and this is facilitated by having the word synchronization information.

A detailed description of the MSS data format is printed in the Landsat D Data Format Control Book, Volume V (Payload), Document SVS-10122.

17.2 MSS PERFORMANCE CAPABILITIES

The Multi Spectral Scanner's general performance parameters are tabulated below:

IFOV	117.2 rad
Orbit Altitude	705.3 Kilometers
Swath Width	185 Kilometers
Number of Bands	4
Detectors per band	6
Longitudinal Trace (projected field of view of 6 detectors)	496 meters
Velocity of nadir point	6.75 Kilometer/sec
Field -of-view	14.90 deg, 0.260 rad
Linear scan rate	4.57 deg/sec, 7.98 rad/sec
Mirror scan frequency	13.62 Hz
Scan period	73.42 ms
Turn around time	4 ms
IFOV's pwer swath	2,346
Samples per active scan	3,270
Active scan period	32.6 ms per scan period
Kel sampling rate	1.46 samples/IFOV width

Spatial frequency at kel sampling rate	56.6 meters
Video frequency for 68.6 meter ft. bars	41 KHz
Video bandwidth per limit	38.2 meters 77 KHz
Channel sampling rate	100.4175K samples/sec
Channel repeat sample time	9.958 microseconds
Word time	0.398 microseconds
Bit rate	15,062,630.4 bits/sec.

17.3 MODES OF OPERATION

There are several MSS Operating Modes and system configurations. The MSS has two basic configurations; primary and redundant. A combination of primary and redundant functions can be employed if required. The modes of operation are; launch, standby and operating. The MSS amplifiers for Band 1 and 2 have two modes, high and low gain. For bands 1, 2 and 3, the MSS Mux can operate in the linear signal amplification or signal compression modes. Band 4 only operates in the low gain linear amplification mode. These modes and configurations are discussed below:

17.3.1 MSS SYSTEM CONFIGURATIONS

17.3.1.1 Primary

The MSS is configured for primary operations by selecting all the "A" designated functions Table 17.1-1 shows the functional status of the components in the configuration.

17.3.1.2 Redundant

When all the "B" designated functions are selected the MSS is configured for redundant operation (see Table 17.1-1).

Table 17.1-1. MSS Mode/Configuration Definition

	Note	Launch Mode	Standby*	Operating Mode Primary(A)	Operating Mode Redundant(B)
SYSTEM PWR A		ON	OFF	ON	OFF
SYSTEM PWR B		OFF	OFF	OFF	ON
MODE		LAUNCH	OPERATE	OPERATE	OPERATE
BAND 1 HV A		OFF	ON	ON	OFF
BAND 1 HV B		OFF	OFF	OFF	ON
BAND 2 HV A		OFF	ON	ON	OFF
BAND 2 HV B		OFF	OFF	OFF	ON
BAND 3 HV A		OFF	ON	ON	OFF
BAND 3 HV B		OFF	OFF	OFF	ON
BAND 1	1	OFF	ON	ON	ON
BAND 2	1	OFF	ON	ON	ON
BAND 3	1	OFF	ON	ON	ON
BAND 4	1	OFF	ON	ON	ON
ROTATING SHUTTER DRIVER	2	ON	OFF	ON	ON
SHUTTER MON. SOURCE A		ON	ON	ON	OFF
SHUTTER MON, SOURCE B		OFF	OFF	OFF	ON
CALIB. LAMP A		OFF	ON	ON	OFF
CALIB. LAMP B		OFF	OFF	OFF	ON
SCAN MON SOURCE A		OFF	ON	ON	OFF
SCAN MON SOURCE B		OFF	OFF	OFF	ON
MIDSCAN CODE	3	OFF	OFF	OFF	OFF
MUX	4	COMPRESSED	COMPRESSED	COMPRESSED	COMPRESSED
BAND 1 GAIN	5	LOW	LOW	LOW/HIGH	LOW/HIGH
BAND 2 GAIN	5	LOW	LOW	LOW/HIGH	LOW/HIGH

NOTES:

1. Bands can be individually activated or deactivated by command.

2. Shutter is rotating in launch mode.

*System off mode, could be in Redundant (B) configuration.

Table 17.1-1. MSS Mode/Configuration Definition

			Operating Mode	
Note	Launch Mode	Standby*	Primary(A)	Redundant(B)

3. Midscan code may be commanded to output midscan code for scan motion diagnostics.

4. Band 1-3 data is normally compressed by the multiplexer to match the signal to noise characteristics of the photomultiplier tubes but can be processed in a linear manner by command.

5. Bands 1 and 2 can be individually commanded to high gain (3:1) for sensing low light level scenes.

17.3.1.3 Combination of Primary and Redundant Functions

This configuration is a mix of "A" and "B" functions. This configuration is used only as components degrade below acceptable limits as a result of orbital operation or the failure of redundant element.

17.3.2 MSS SYSTEM MODES

17.3.2.1 Launch Mode

For launch the MSS will be placed in launch mode with compouents configured as shown in Table 17.1-1. The MSS is to be launched in the minimum power state consistent with requirement that the rotating shutter be "ON".

17.3.2.2 Standby Mode

The status of the MSS components in the Standby Mode is shown in Table 17.1-1. This mode is used when the MSS is not in use imaging.

17.3.2.3 Operating Mode

Whenever MSS sensor data is required the system is placed in the normal Operating Mode as shown in Table 17.1-1. This mode may be configured as primary, redundant or a combination of primary and redundant functions.

17.3.3 BAND 1 AND 2 AMPLIFIER MODES

The Band 1 and Band 2 video sensor data from the photomultiplier tubes can be commanded into a low gain or high gain (3:1) mode. High gain is used for sensing low light level scenes. Band 3 and 4 remain in low gain and are not commandable to high gain mode.

17.3.4 MULTIPLEXER MODES

The MSS Multiplexer may be commanded into two modes, Linear and Compression. The video signals from Bands 1-3 can be directed by command to a linear amplifier or a compression amplifier prior to encoding. The compression amplifier enhances noise characteristics for better sensor resolution.

17.4 MSS CONSTRAINTS

17.4.1 MSS INITIALIZATION CONSTRAINTS

1. After launch insertion, a minimum of ten hours is required for outgassing prior to turn-on to verify outgassing period (no high voltage arcing).

2. The scanner and scan mirror must be given a 3-minute warm up period prior to collection of data for radiometric annalysis or sun calibration.

17.4.2 MSS TELEMETRY CONSTRAINTS

All voltage, current and miscellaneous telemetry functions should be within specified limits. Data will be processed at ground station, and limits shall be alarmed when exceeded.

17.4.3 MSS COMMAND CONSTRAINTS

1. When the MSS system is configured in the Launch Mode, the transmission of the "Mode Operate" command may cause the MSS power to be turned-off automatically. This causes no damage but should be avoided. The "System Power A ON (or B ON)" must then be sent to turn the power back ON. To avoid this possible turn off situration, the "SYSTEM POWER OFF" command must be transmitted prior to re-transmission of the "MODE OPERATE" command.

2. It is possible to command both power supplies on at the same time. This results in somewhat greater power drain but causes no damage. "SYSTEM POWER OFF" command should be sent before sending "SYSTEM POWER A ON (or B ON)" command.

17.4.4 MSS TEMPERATURE CONSTRAINTS

1. The MSS shall be commanded "OFF" whenever any MSS temperature reaches the maximum limits listed below. The MSS (IM) heater shall be turned on if any temperature falls below $0^{o}C$ ($32^{o}F$).

Power supplies	$123^{o}F$	$51^{o}C$
Electronic cover	$123^{o}F$	$51^{o}C$
Fiber optics plate	$108^{o}F$	$42^{o}C$
Scan mirror regulator	$140^{o}F$	$60^{o}C$
Scan mirror drive electronics	$140^{o}F$	$60^{o}C$
Scan mirror coil	$180^{o}F$	$82^{o}C$
Scan mirror housing	$122^{o}F$	$50^{o}C$
Multiplexer	$130^{o}F$	$55^{o}C$

17.4.5 MSS PRESSURE CONSTRAINTS

1. The MSS high voltage turn-on is to take place only after 10 hours (minimum) of outgassing after the flight segment is exposed to a vacuum environment of 10^{-5} Torr or less.

17.4.6 MSS VIEWING CONSTRAINTS

1. At no time is the MSS FOV to be pointed directly at the sun. Such viewing within a 7 1/2° cone angle relative to the MSS boresight (Z) axis will cause permanent damage. Sun exposure within the region bounded by half cone angles of 7 1/2° and 63° shall be limited to 55 minutes maximum.

17.4.7 MSS OPERATING MODE CONSTRAINTS

1. The MSS operating duty cycle shall not exceed 33% of an orbital period of 99 minutes.

2. During launch or vibration, the MSS shall be operated with rotating shutter "ON".

17.4.8 MSS SAFE-HOLD CONSTRAINTS

1. Command IM/MSS I/F Heaters "ON" is not previously ON, to allow thermostatically controlled heaters A and B to operate.

2. Ground command, "SYSTEM OFF", after the flight segment has returned from SAFE-HOLD mode to the earth pointing mode again and solar array is in the normal orbit configuration, and MSS power has been re-enabled in the PDU.

17.4.9 MSS LAUNCH MODE CONSTRAINTS

1. The scanner rotating system should be on and High Voltage OFF.

17.5 REDUNDANCY

As shown in Paragraph 17.3 the MSS has three operational modes, primary, redundant and mixed. The primary mode uses the A components, the redundant mode uses the B components, and the combined Primary/Redundant mode uses A and B components. The redundant components are listed below:

PRIMARY POWER SUPPLY A
PREREGULATOR A
INVERTER A
PRIMARY POWER SUPPLY B
PREREGULATOR B
INVERTER B
BAND 1 HV PWR SUPPLY A
BAND 1 HV PWR SUPPLY B
BAND 2 HV PWR SUPPLY A
BAND 2 HV PWR SUPPLY B
BAND 3 HV PWR SUPPLY A
BAND 3 HV PWR SUPPLY B

CALIBRATION LAMP A
CALIBRATION LAMP B
SCAN MONITOR A
SCAN MONITOR B
SHUTTER MONITOR A
SHUTTER MONITOR B

There are three types of cross-strapping: dedicated, active and passive. Active cross-strapping is where primary and redundant components both feed a third unit. There is no active cross-strapping in the MSS. Passive cross-strapping invovles the selection of the Primary (A) or Redundant (B) component by command switching as in the interfaces shown on Figure 17.5-1. marked with P . Dedicated comoponents are used together and cannot be crossed-strapped as in the MSS power supply, preregulator and inverter (i.e., power supply A cannot power preregulator B nor can preregulator A power inverter B and vice-versa). Figure 17.5-1 shows the cross-strapping in the MSS Subsystem.

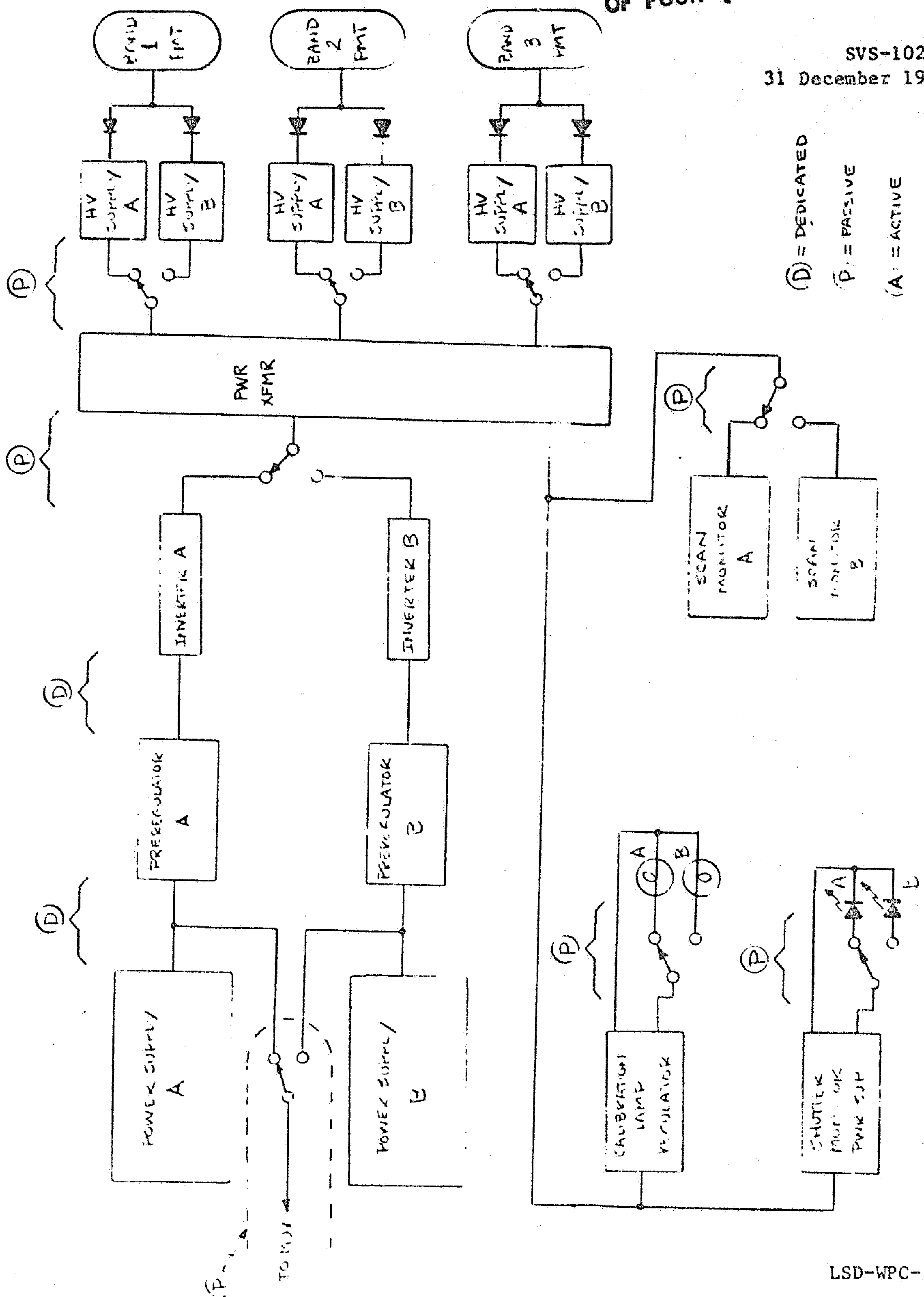

Figure 17.5-1. MSS Cross-Strapping/Redundancy

17.6 MSS COMMANDS

The operation of the MSS is controlled by 37 discrete commands directly to the MSS, and 5 discrete commands to the PDU. In addition, MSS thermal control is achieved by 2 discrete commands to the PDU and 6 discrete commands to the SCCU. The MSS commands are listed in Table 17.6-1. MSS commands and related PDU and SCCU commands are described in Paragraph 17.6.1. Applicable PDU and SCCU commands are listed in Tables 17.6-2 and 17.6-3, respectively. Standard MSS command sequences are provided in Paragraphs 17.6.2. MSS command constraints are defined in Paragraph 17.6.3.

This section also provides functional schematics of the command circuits as an aid to understanding the command interface. Note, however, that the functional schematics are provided as information only; they are superseded by the exact circuits shown on the engineering drawings.

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Table 17.6-1. Multi-Spectral Scanner Discrete Commands

COMMAND NAME	ACRONYM	RIU-CH	COMPLEMENT	VERIFICATION ACRONYM	VERIFICATION STATE	VERIFICATION LOCATION	RIU-CH
SYS PWR A ON	SYSAON	7-01	SYSOFF	MPSYSA	1	96-00-BIT 1	07-65
				MPSCMRL1	0	97-00-BIT 3	08-35
				MPSCMRL2	1	97-00-BIT 4	08-36
				MPSCMR	0	97-00-BIT 5	08-37
BD1 HVA ON/B OFF	BD1HVAON	7-05	BD1HVBON	MPBD1HVA	1	99-00-BIT 1	08-121
			BD1HVOFF	MPBD1HVB	0	99-00-BIT 2	08-122
BD2 HVA ON/B OFF	BD2HVBON	8-06	BD2HVBON	MPBD2HVA	1	99-00-BIT 3	08-123
			BD2HVOFF	MPBD2HVB	0	99-00-BIT 4	08-124
BD3 HVA ON/OFF	BD3HVAON	7-11	BD3HVBON	MPBD3HVA	1	99-00-BIT 5	08-125
			BD3HVOFF	MPBD3HVB	0	99-00-BIT 5	08-126
CALLMP A ON/B OFF	CALMPAON	8-55	CALMPBON	MPCALLP	1	96-00-BIT 4	07-68
			CALMPOFF	MSCALLP	1	96-00-BIT 5	07-69
SHTR MON A ON/B OFF	SHMONAON	7-27	SHMONBON	MSSHRMON	1	96-00-BIT 6	07-70
SCAN MON A ON/B OFF	SCMONAON	7-31	SCMONBON	MSSCNMON	1	96-00-BIT 7	07-71
SYS PWR B ON	SYSBON	8-62	SYSOFF	MPSYSB	1	96-00-BIT 2	07-66
				MPSCMRL1	1	97-00-BIT 3	08-35
				MPSCMRL2	0	97-00-BIT 4	08-36
				MPSCMR	0	97-00-BIT 5	08-37
BD1 HVB ON/A OFF	BD1HVBON	7-35	BD1HVAON	MPBD1HVB	1	99-00-BIT 2	08-122
			BD1HVOFF	MPBD1HVA	0	99-00-BIT 1	08-121
BD2 HVB ON/A OFF	BD2HVBON	8-48	B2HVAON	MPBD2HVA	0	99-00-BIT 3	08-123
			B2HVOFF	MPBD2HVB	1	99-00-BIT 4	08-124
BD3 HVB ON/A OFF	BD3HVBON	7-37	BD3HVAON	MPBD3HVA	0	99-00-BIT 5	08-125
			BD3HVOFF	MPBD3HVB	1	99-00-BIT 6	08-126
CALLMP B ON/A OFF	CALMPBON	8-28	CALMPAON	MSCALLP	0	96-00-BIT 5	07-69
			CALMPOFF	MPCALLP	1	96-00-BIT 4	07-68
SHTR MON B ON/A OFF	SHMONBON	7-39	SHMONAON	MSSHRMON	0	96-00-BIT 6	07-70
SCAN MON B ON/A OFF	SCMONBON	7-33	SCMONAON	MSSCNMON	0	96-00-BIT 7	07-71
BAND 1 LV ON	BD1ON	8-12	BD1X40FF	MPBD1LV *	1	98-00-BIT 2	08-50
BAND 2 LV ON	BD2ON	8-40	BD1X40FF	MPBD2LV *	1	98-00-BIT 3	08-51
BAND 3 LV ON	BD3ON	8-54	BD1X40FF	MPBD3LV *	1	98-00-BIT 4	08-52
BAND 4 ON	BD4ON	7-17	BD1X40FF	MPBD4LV *	1	98-00-BIT 5	08-53
HI VOLTAGE ON	HVON	8-58	SYSOFF	MPSYSHV	1	99-00-BIT 0	08-120
ROT SHUTTER DRIVE ON	SHDRON	7-19	SHDROFF	MPROTSHD	1	96-00-BIT 3	07-67
				MXSHRROT	1	99-00-BIT 7	08-127
MID SCAN CODE ON	MSCON	7-55	MSCOFF	MSMSCODE	0	97-00-BIT 7	08-39

*NOT FULL-TIME TELEMETRY

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Table 17.6-1. Multi-Spectral Scanner Discrete Commands (Continued)

COMMAND NAME	ACRONYM	RIU-CH	COMPLEMENT	VERIFICATION			RIU-CH
				ACRONYM	STATE	LOCATION	
SYS PWR OFF	SYSOFF	7-53	SYSAON	MPSYSA	0	96-00-BIT 1	07-65
			SYSBON	MPSYSB	0	96-00-BIT 2	07-66
				MPSYSHV	0	99-00-BIT 0	08-120
				MPSCMR	1	97-00-BIT 5	08-37
BD1 HV OFF	BD1HVOFF	7-09	BD1HVAON	MPBD1HVA	0	99-00-BIT 1	08-121
			BD1HVBON	MPBD1HVB	0	99-00-BIT 2	08-122
BD2 HV OFF	BD2HVOFF	8-10	BD2HVAON	MPBD2HVA	0	99-00-BIT 3	08-123
			BD2HVBON	MPBD2HVB	0	99-00-BIT 4	08-124
BD3 HV OFF	BD3HVOFF	7-23	BD3HVAON	MPBD3HVA	0	99-00-BIT 5	08-125
			BD3HVBON	MPBD3HVB	0	99-00-BIT 6	08-126
BDS1-4 OFF	PD1X4OFF	8-26	BD1LVON	MPBD1LV *	0	98-00-BIT 2	08-50
			BD2LVON	MPBD2LV *	0	98-00-BIT 3	08-51
			BD3LVON	MPBD3LV *	0	98-00-BIT 4	08-52
			BD4ON	MPBD4LV *	0	98-00-BIT 5	08-53
ROT SHTR DRIVE OFF	SHDROFF	8-14	SHDRON	MPROTSHD	0	96-00-BIT 3	07-67
				MXSHRROT	0	99-00-BIT 7	08-127
CAL LAMPS OFF	CALMPOFF	8-38	CALMPAON	MPCALLP	0	96-00-BIT 4	07-68
			CALMPBON				
SCAN MONITOR OFF	SCMONOFF	7-07	MODEOPER	MPSCNMON*	0	97-00-BIT 1	08-33
MID SCAN CODE OFF	MSCOFF	8-42	MSCON	MSMSCODE	1	97-00-BIT 7	08-39
MODE OPERATE	MODEOPER	8-32	SCMONOFF	MXSCMRIN	0	97-00-BIT 0	08-32
			MODELNCH	MPSCNMON*	1	97-00-BIT 1	08-33
				MPMUX	1	97-00-BIT 2	08-34
MODE LAUNCH	MODELNCH	7-51	MODEOPER	MXSCMRIN	1	97-00-BIT 0	08-32
				MPMUX	0	97-00-BIT 2	08-34
MUX LINEAR	MUXLIN	7-49	MUXCOMP	MSMUXCL	0	97-00-BIT 6	8-38
MUX COMPRESSED	MUXCOMP	8-36	MUXLIN	MSMUXCL	1	97-00-BIT 6	8-38
BAND 1 HI GAIN	BD1HIGN	7-21	BD12LOGN	MSBD1GHL	1	96-00-BIT 0	8-48
BAND 2 HI GAIN	BD2HIGN	8-22	BD12LOGN	MSBD2GHL	1	98-00-BIT 1	8-49
BANDS 1 & 2 LO GAIN	BD12LOGN	7-43	BD1HIGN	MSBD1GHL	0	98-00-BIT 0	8-48
			BD2HIGN	MSBD2GHL	0	98-00-BIT 1	8-49

*NOT FULL-TIME TELEMETRY

Table 17.6-2. PDU Command List (Applicable to MSS)

COMMAND NAME	ACRONYM	RIU-CH	COMPLEMENT	VERIFICATION			RIU-CH
				ACRONYM	STATE	LOCATION	
MSS PWR A ENA	ENMSSA	6-03	DISMSS	YMSAPWR	1	33-85-BIT 4	06-12
MSS PWR B ENA	ENMSSB	6-06	DISMISS	YMSBPWR	1	33-85-BIT 5	06-13
MSS PWR DIS	DISMSS	6-33	ENMSSA	YMSAPWR	0	33-85-BIT 4	06-12
			ENMSSB	YMSBPWR	0	33-85-BIT 5	06-13
MSS IF B HTR EN	EMSSHTRB	6-12	DMSSHTRB	YMSHTB	1	33-86-BIT 3	06-35
MSS IF B HTR DIS	DMSSHTRB	6-41	EMSSHTRB	YMSHTB	0	33-86-BIT 3	06-35

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Table 17.6-3. SCCU Command List (Applicable to MSS)

COMMAND NAME	ACRONYM	PIU-CH	COMPLEMENT	VERIFICATION			PIU-CH
				ACRONYM	STATE	LOCATION	
MSSIFAPRIHTREN	MSHAEN	4-70 X7214	4-70 X82E4	UMSAHTA	1	97-04-BIT 5	04-01
[illegible]APRIHTRDIS	MSHADI	4-70 X82E4	4-70 X7214	UMSAHTA	0	97-04-BIT 5	04-01
MSSIFAREDHTREN	MSHBEN	4-70 X9264	4-70 XA2A4	UMSAHTB	1	97-04-BIT 6	04-01
MSSIFAREDHTRDIS	MSHBDI	4-70 XA2A4	4-70 X9264	UMSAHTB	0	97-04-BIT 6	04-01
MSSIFAHTRTHBY	MSTHBY	4-70 XB224	4-70 XC2C4	UMSATHT	1	97-04-BIT 7	04-01
MSSIFAHTRTHEN	MSTHEN	4-70 XC2C4	4-70 XB224	UMSATHT	0	97-04-BIT 7	04-01

17.6.1 COMMAND DESCRIPTION

17.6.1.1 (CMD 701) System Power "A" On

Execution of the "System Power A On" command (SYSAON) applies spacecraft power to primary power supply 1 and selects scan mirror power line 1. SYSAON sets relays K1, K5, K6, K7 and K29. K1 sets K3 via a pulse stretcher circuit (see Figure 17.6-1). The system off command should be transmitted and verified prior to transmission of this command to avoid energizing both primary power supplies simultaneously.

17.6.1.2 (CMD 862) System Power "B" On

Execution of the "System Power B On" command (SYSBON) applies spacecraft power to primary power supply 2 and selects scan mirror power line 2. SYSBON sets relay K2 and resets relays K5, K6, K7 and K29. K2 sets K4 via a pulse stretcher circuit (see Figure 17.6-1). The system off command should be transmitted and verified prior to transmission of this command to avoid energizing both primary power supplies simultaneously.

17.6.1.3 (CMD 753) System Power Off

Execution of the system power off command (SYSOFF) removes all system power except full time bi-level telemetry power and also disables the 42 VAC secondary power inputs to the high voltage power supplies for the Photo-Multiplier Tube (PMT) Bands (1, 2 and 3). SYSOFF resets relays K1, K2, K8 and K9. K1 resets K3 and K2 resets K4 via the respective pulse stretcher circuits (see Figure 17.6-1).

17.6.1.4 (CMD 858) Hi Voltage On

Execution of the high voltage on command (HVON) enables the 42 VAC secondary inputs to selected prime (A) or redundant (B) high voltage power supplies for (PMT) Bands 1, 2 and 3). HVON sets relays K8 and K9. See Figure 17.6-2. Under a vacuum environment, a 10 hour outgas period is required prior to transmission of this command to prevent possible arcing.

17.6.1.5 (CMD 705) Band 1 High Voltage A On, B Off

Execution of the Band 1 High Voltage A On/B Off command (BD1HVAON) connects the primary of Band 1 High Voltage Power Supply (A) Transformer and disconnects the redundant Band 1 High Voltage Power Supply (B) transformer primary at the Band 1 42 VAC contact of the high voltage on relay K8. BD1HVAON sets relay K10 and resets K11 (see Figure 17.6-2).

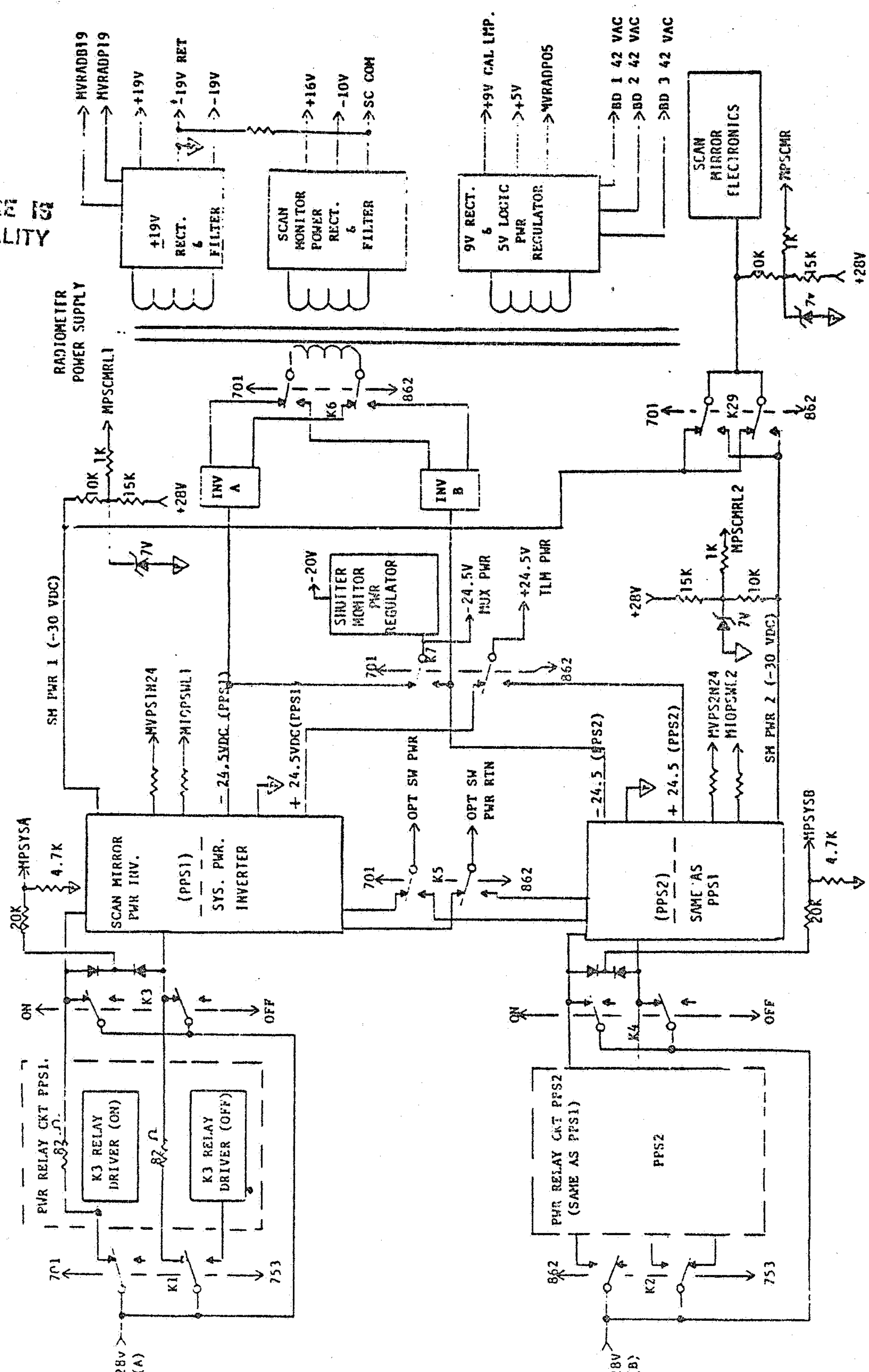

Figure 17.6-1. Power CMD CKT

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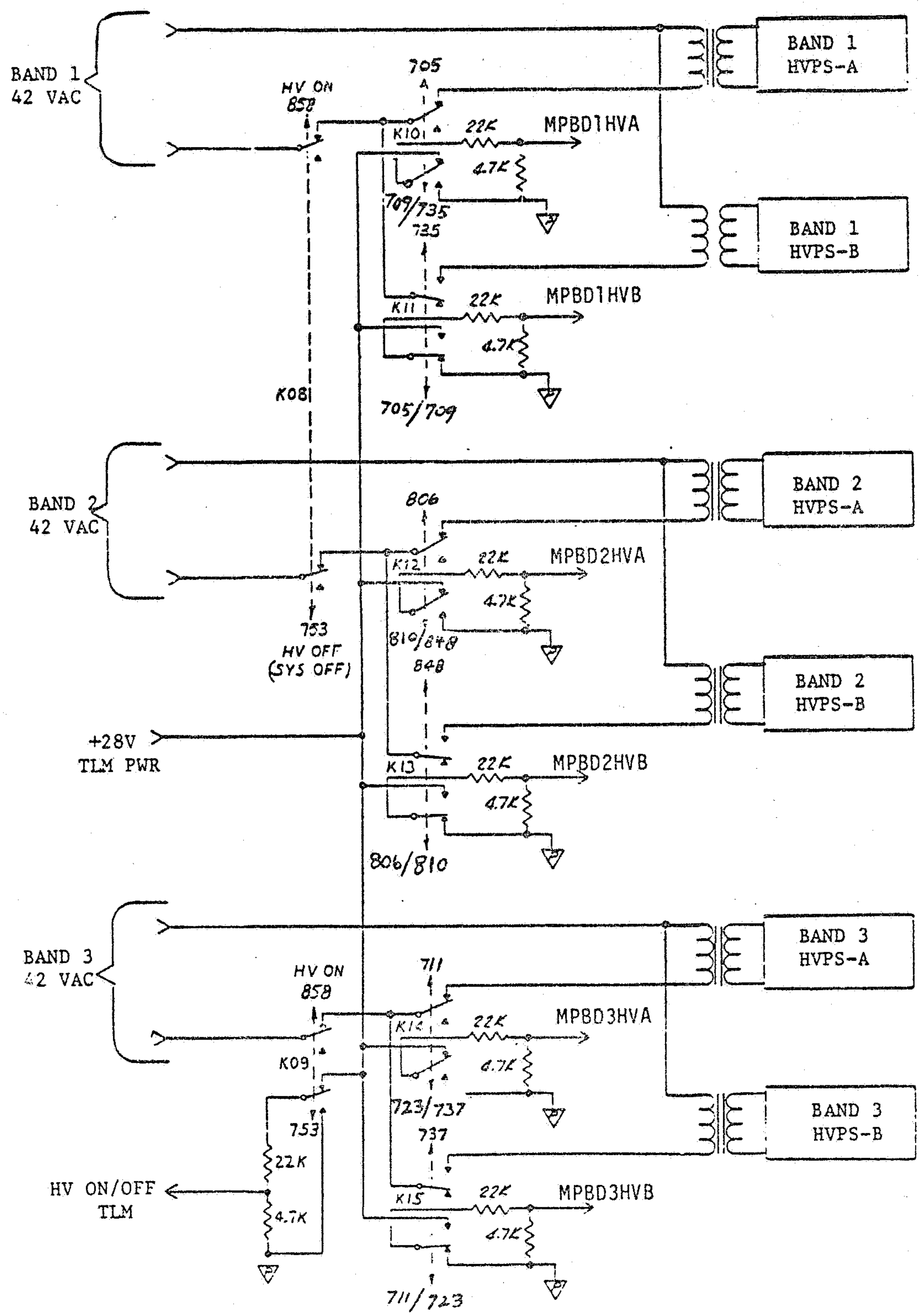

Figure 17.6-2. HV CMD CKT

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17.6.1.6 (CMD 806) Band 2 High Voltage A On/B Off

Execution of the Band 2 High Voltage A On, B Off command (BD2HVAON) connects the primary of Band 2 High Voltage Power Supply (A) Transformer and disconnects the redundant Band 2 High Voltage Power Supply (B) Transformer primary at the Band 2 42 VAC contact of the high voltage on relay K8. BD2HVAON sets relay K12 and resets K13 (see Figure 17.6-2).

17.6.1.7 (CMD 711) Band 3 High Voltage A On/B Off

Execution of the Band 3 High Voltage A On, B Off command (BD3HVAON) connects the primary of Band 3 High Voltage Power Supply (A) Transformer and disconnects the redundant Band 3 High Voltage Power Supply (B) Transformer primary at the 42 VAC contact of the high voltage on relay K9. BD3HVAON sets relay K14 and resets K15 (see Figure 17.6-2).

17.6.1.8 (CMD 735) Band 1 High Voltage B On, A Off

Execution of the Band 1 High Voltage B On, A Off command (BD1HVBON) connects the primary of Band 1 High Voltage Power Supply (B) Transformer and disconnects the prime Band 1 High Voltage Power Supply (A) Transformer primary at the Band 1 42 VAC contact of the high voltage on relay K8. BDVHVBON sets relay K11 and resets K10 (see Figure 17.6-2).

17.6.1.9 (CMD 848) Band 2 High Voltage B On, A Off

Execution of the Band 2 High Voltage B On, A Off command (BD2HVBON) connects the primary of Band 2 High Voltage Power Supply (B) Transformer and disconnects the prime Band 2 High Voltage Power Supply (A) Transformer primary at the Band 2 42 VAC contact of the high voltage on relay K8. BD2HVBON sets relay K13 and resets K12 (see Figure 17.6-2).

17.6.1.10 (CMD 737) Band 3 High Voltage B On, A Off

Execution of the Band 3 High Voltage B On, A Off command (BD3HVBON) connects the primary of Band 3 redundant High Voltage Power Supply (B) Transformer and disconnects the prime Band 3 High Voltage Power Supply (A) Transformer primary at the Band 3 42 VAC contact of the high voltage on relay K9. BD3HVBON sets relay K15 and resets K14 (see Figure 17.6-2).

17.6.1.11 (CMD 709) Band 1 High Voltage Off

Execution of the Band 1 High Voltage Off command (BD1HVOFF) disconnects the primaries of the prime and redundant (A&B) Band 1 High Voltage Power Supply Transformers from the Band 1 42 VAC input line. BD1HVOFF resets relays K10 and K11 (see Figure 17.6-2).

17.6.1.12 (CMD 810) Band 2 High Voltage Off

Execution of the Band 2 High Voltage Off command (BD2HVOFF) disconnects the primaries of the prime and redundant (A&B) Band 2 High Voltage Power Supply Transformers from the Band 2 42 VAC input line. BD2HVOFF resets relays K12 and K13 (see Figure 17.6-2).

17.6.1.13 (CMD 723) Band 3 High Voltage Off

Execution of the Band 3 High Voltage Off command (BD3HVOFF) disconnects the primaries of the prime and redundant (A&B) Band 3 High Voltage Power Supply Transformers from the Band 3 42 VAC input line. BD3HVOFF resets relays K14 and K15 (see Figure 17.6-2).

17.6.1.14 (CMD 812) Band 1 Low Voltage On

Execution of the Band 1 Low Voltage On command (BD1ON) applies ±19 VDC to the Band 1 ±15 VDC regulator, which supplies power to the Band 1 Video Preamplifiers and PMT Buffer Amplifiers. BD1ON sets relay K16 (see Figure 17.6-3).

17.6.1.15 (CMD 840) Band 2 Low Voltage On

Execution of the Band 2 Low Voltage on command (BD2ON) applies ±19 VDC to the Band 2 ±15 VDC regulator, which supplies power to the Band 2 Video Preamplifiers and PMT Buffer Amplifiers. BD2ON sets relay K17 (see Figure 17.6-3).

17.6.1.16 (CMD 854) Band 3 Low Voltage On

Execution of the Band 3 Low Voltage on command (BD3ON) applies ±19 VDC to the Band 3 ±15 VDC regulator, which supplies power to the Band 3 Video Preamplifiers and PMT Buffer Amplifiers. BD3ON sets relay K18 (see Figure 17.6-3).

17.6.1.17 (CMD 717) Band 4 Low Voltage On

Execution of the Band 4 Low Voltage on command (BD4ON) applies ±19 VDC to the Band 4 ±15 VDC regulator, which suplies power to the Band 4 Silicon Diode Detector, DC restore circuits and Buffer Amplifiers. BD4ON sets relay K19 (see Figure 17.6-3).

17.6.1.18 (CMD 826) Bands 1 through 4 Off

Execution of the Bands 1 through 4 Off command (Bd1X4OFF) removes ±19 VDC power from the four ±15 VDC regulators powering video amplifiers in respective bands. BD1X4OFF resets relays K16, K17, K18 and K19 (see Figure 17.6-3).

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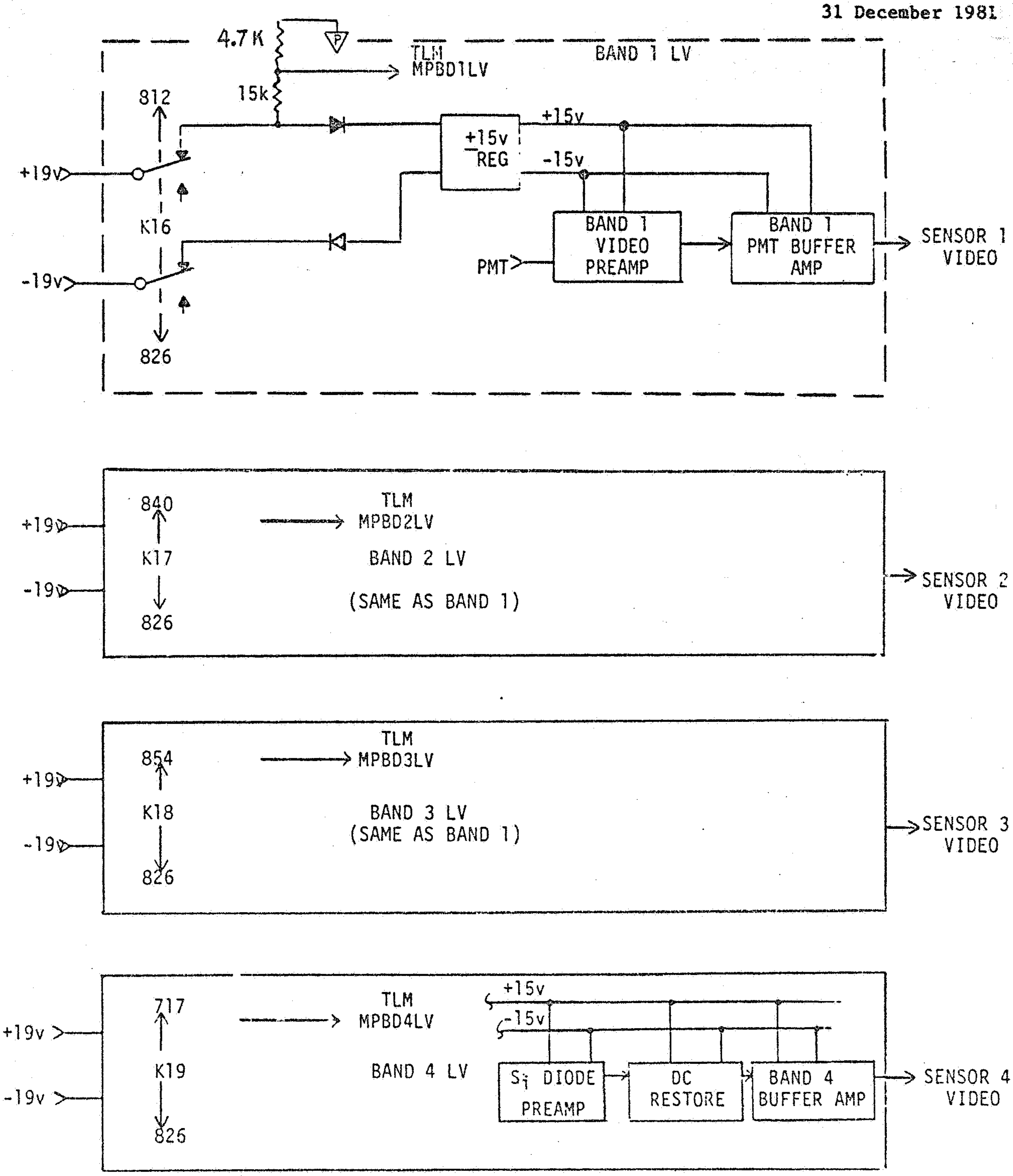

Figure 17.6-3. Band LV CMD CKT's

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17.6.1.19 (CMD 721) Band 1 High Gain

Execution of the Band 1 High Gain command (BD1HIGN) increases Band 1 PMT Buffer Amplifier gain by a factor of 3. BD1HIGN sets relay K20 (see Figure 17.6-4).

17.6.1.20 (CMD 822) Band 2 High Gain

Execution of the Band 2 High Gain command (BD2HIGN) increases Band 2 PMT Buffer Amplifier gain by a factor of 3. BD2HIGN sets relay K21 (see Figure 17.6-4).

17.6.1.21 (CMD 742) Bands 1 and 2 Low Gain

Execution of the Bands 1 and 2 Low Gain command (BD12LOGN) returns Bands 1 and 2 PMT Buffer Amplifiers to the nominal (Low) Gain mode. BD12LOGN resets relays K20 and K21 (see Figure 17.6-4).

17.6.1.22 (CMD 719) Rotating Shutter On

Execution of the Rotary Shutter on command (SHDRON) enables the rotating shutter motor bridge drivers. SHDRON sets relay K22 (see Figure 17.6-5).

17.6.1.23 (CMD 814) Rotating Shutter Off

Execution of the Rotating Shutter Off command (SHDROFF) disables the rotating shutter motor bridge drivers. SHDROFF resets relay K22 (see Figure 17.6-5).

17.6.1.24 (CMD 727) Shutter Monitor Source A On, B Off

Execution of the Shutter Monitor Source A On, B Off command (SHMONAON) applies constant current power derived from the 9 VDC supply to the prime shutter monitor LED (A) and removes power from the redundant LED (B). SHMONAON sets relay K27 (see Figure 17.6-6).

17.6.1.25 (CMD 739) Shutter Monitor Source B On, A Off

Execution of the Shutter Monitor B On, A Off command (SHMONBON) applies constant current power derived from the 9 VDC supply to redundant shutter monitor LED (B) and removes power from the prime LED (A). SHMONBON resets relay K27 (see Figure 17.6-6).

17.6.1.26 (CMD 856) Calibration Lamp A On, B Off

Execution of the Calibration Lamp A On, B Off command (CALMPAON) applies constant current power derived from the +9 VDC supply to prime Calibration Lamp (A) and removes power from redundant CAL Lamp (B). CALMPAON sets relays K23 and K24 (see Figure 17.6-7).

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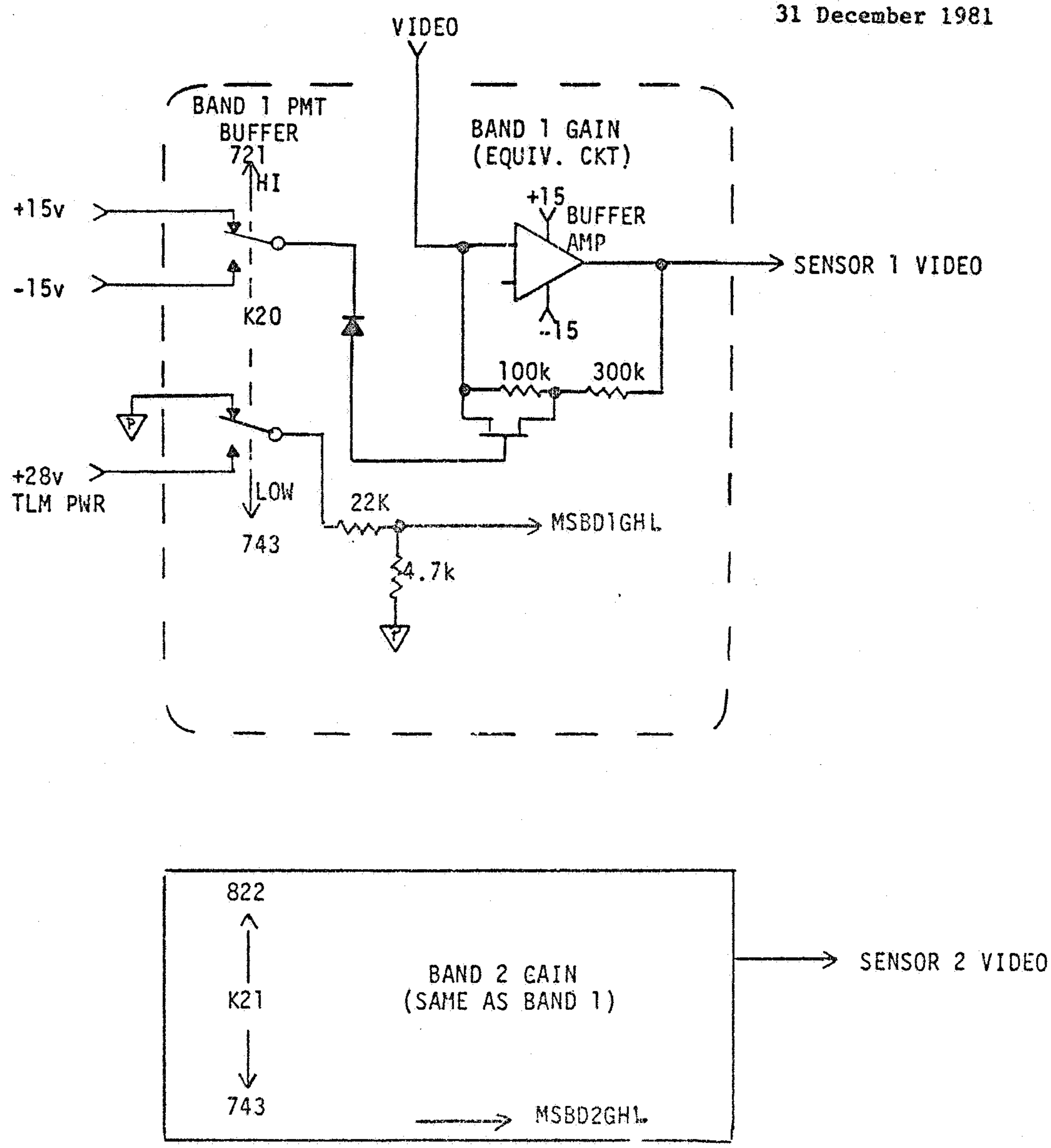

Figure 17.6-4. Band 1 & 2 Gain CMD CKT

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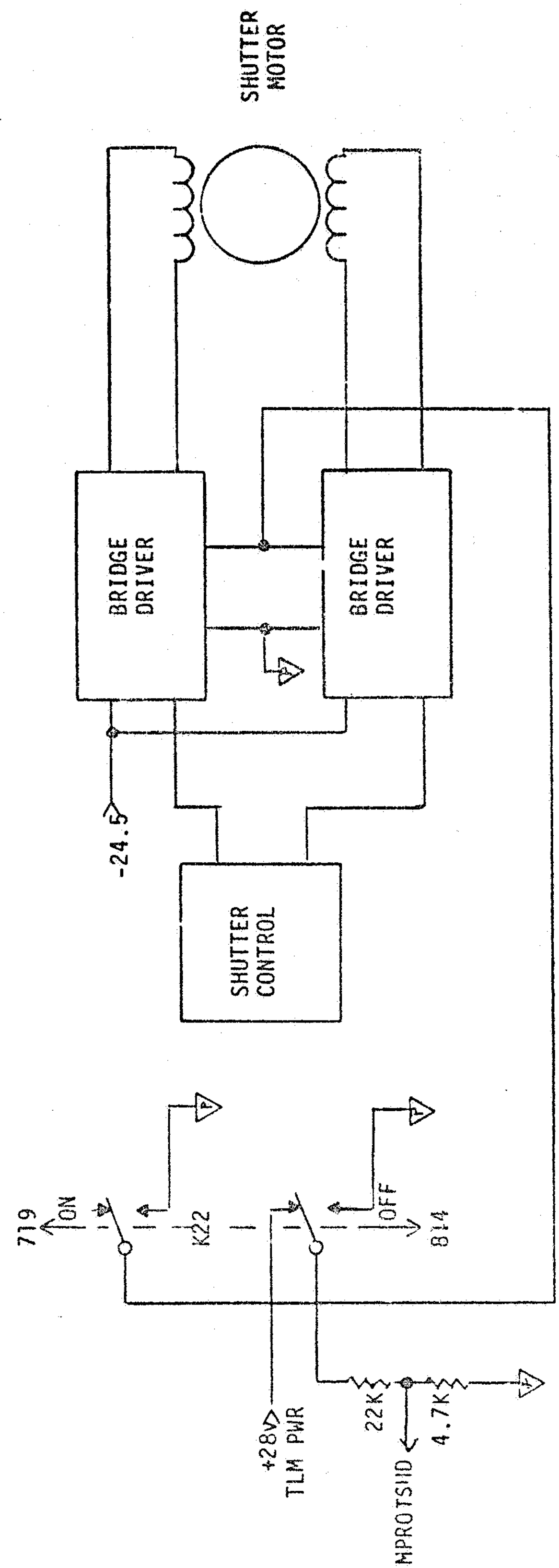

Figure 17.6-5. Rotating Shutter Drive CMD CKT

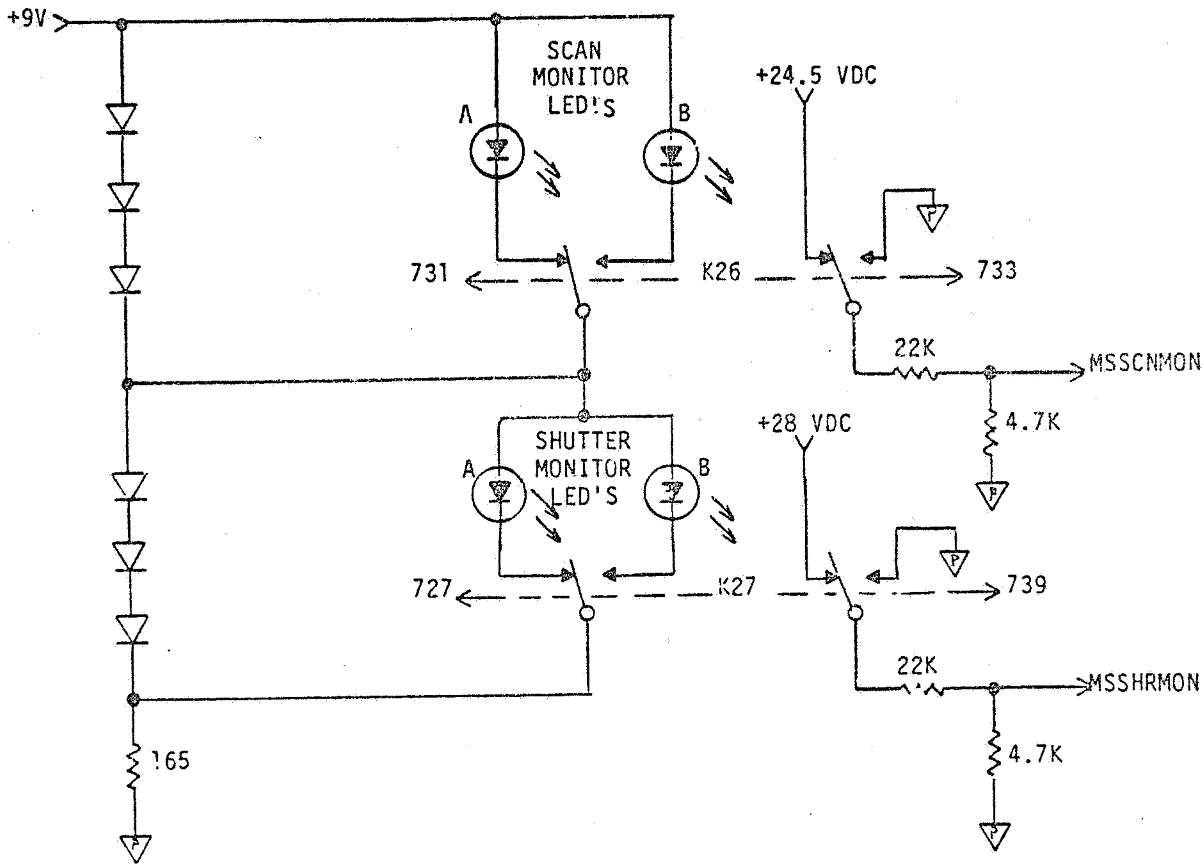

Figure 17.6-6. LED Select CMD CKT

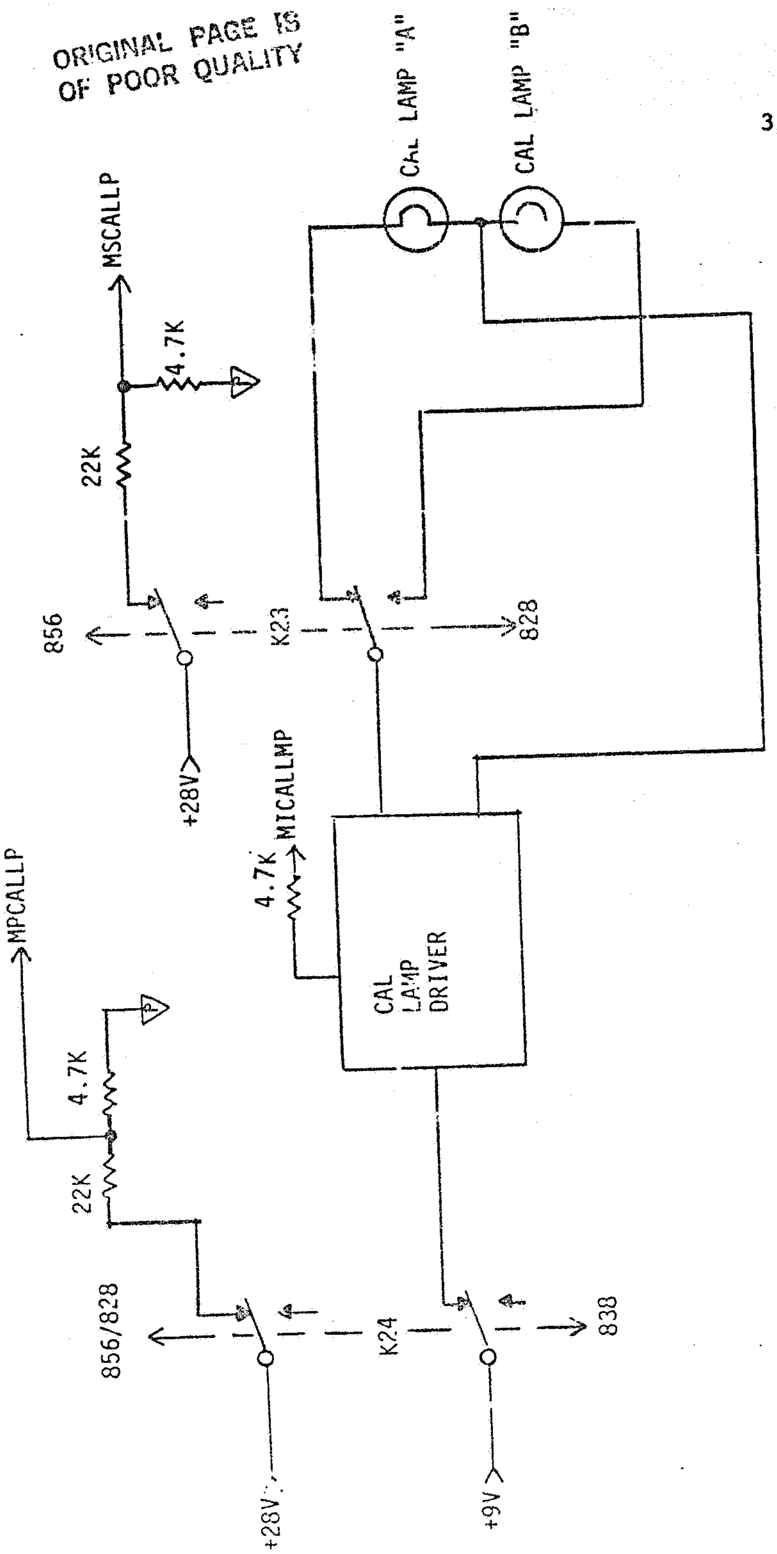

Figure 17.6-7. CAL Lamp CMD CKT

17.6.1.27 (CMD 828) Calibration Lamp B On, A Off

Execution of the Calibration Lamp B On, A Off command (CALMPBON) applies constant current power derived from the +9 VDC supply to the redundant Calibration Lamp (B) and removes power from the prime CAL Lamp (A). CALMPBON resets relay K23 and sets relay K24 (see Figure 17.6-7).

17.6.1.28 (CMD 838) Calibration Lamps Off

Execution of the Calibration Lamps Off command (CALMPOFF) removes power from the selected (A or B) Calibration Lamp. CALMPOFF resets relay K24 (see Figure 17.6-7).

17.6.1.29 (CMD 731) Scan Monitor Source A On, B Off

Execution of the Scan Monitor Source A On, B Off command (SCMONAON) applies constant current power derived from the +9 VDC supply to the prime scan Monitor LED (A) and removes power from the redundant LED (B). SCMONAON sets relay K26 (see Figure 17.6-6).

17.6.1.30 (CMD 733) Scan Monitor Source B On, A Off

Execution of the Scan Monitor Source B On, A Off command (SCMONBON) applies constant current power derived from the +9 VDC supply to the redundant scan Monitor LED (B) and removes power from LED (A). SCMONBON resets relay K26 (see Figure 17.6-6).

17.6.1.31 (CMD 707) Scan Monitor Off

Execution of the Scan Monitor Off command (SCMONOFF) removes power from the Scan Monitor Pulse (SMP) Amplifier and enables multiplexer logic to generate a substitute Scan Monitor Pulse at the nominal line start time. Only the line start code, no end of line or midscan code is available under this condition. SCMONOFF resets relay K25, which in turn de-energizes non-latching relay K30 (see Figure 17.6-8).

17.6.1.32 (CMD 836) Multiplexer Compression

Execution of the Multiplexer Compression command (MUXCOMP) causes Band 1, 2 and 3 MSS Video data to be sampled from Logarithmic Amplifiers in the MUX before A/D conversion (Bands 1 to 3) to linear operation by passing the Logarithmic Amplifiers. MUXCOMP sets relay K32 (see Figure 17.6-9).

17.6.1.33 (CMD 749) Multiplexer Linear

Execution of the Multiplexer Linear command (MUXLIN) switches MUX data conversion (Bands 1 to 3) to linear operation by passing the Logarithmic Amplifiers. MUXLIN resets relay K32 (see Figure 17.6-9).

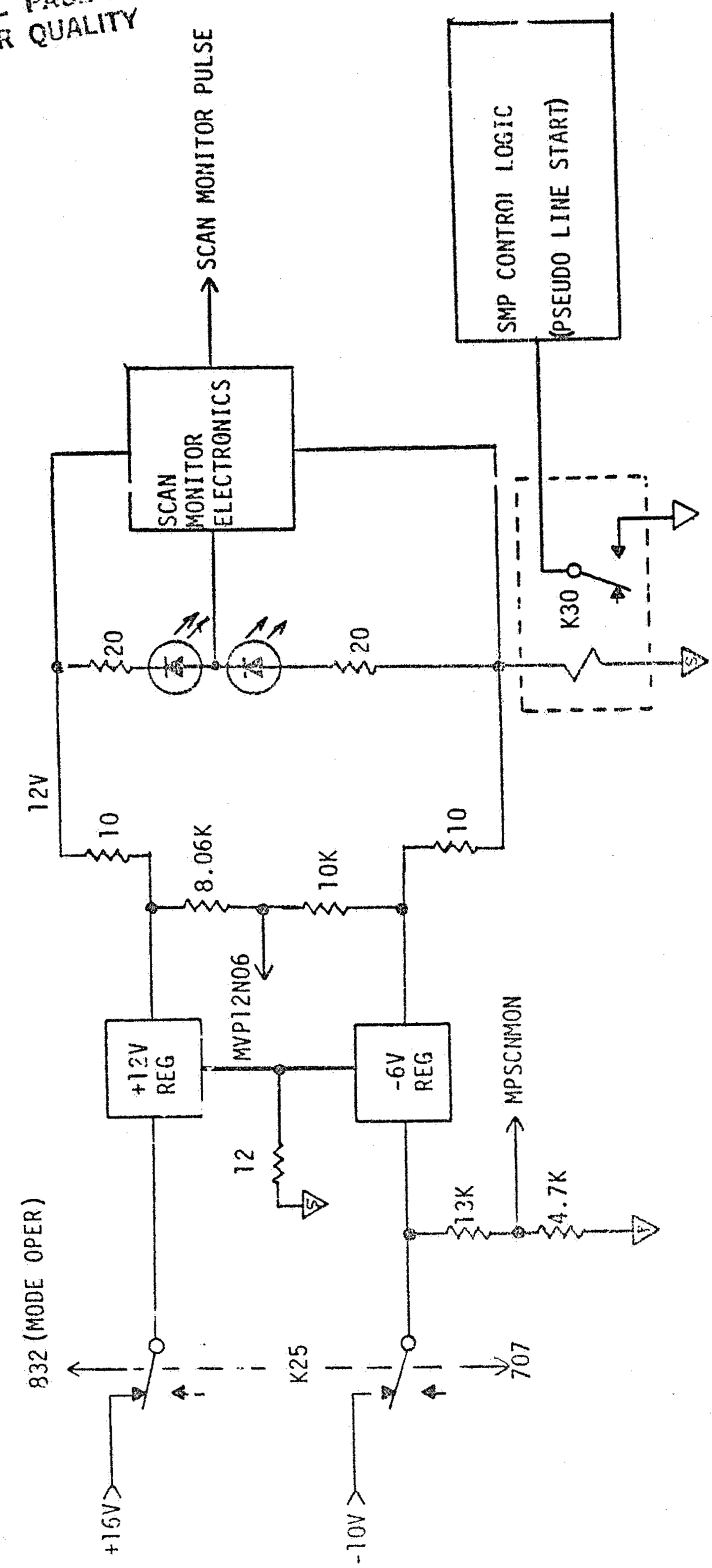

Figure 17.6-8. Scan Monitor Pulse CMD CKT

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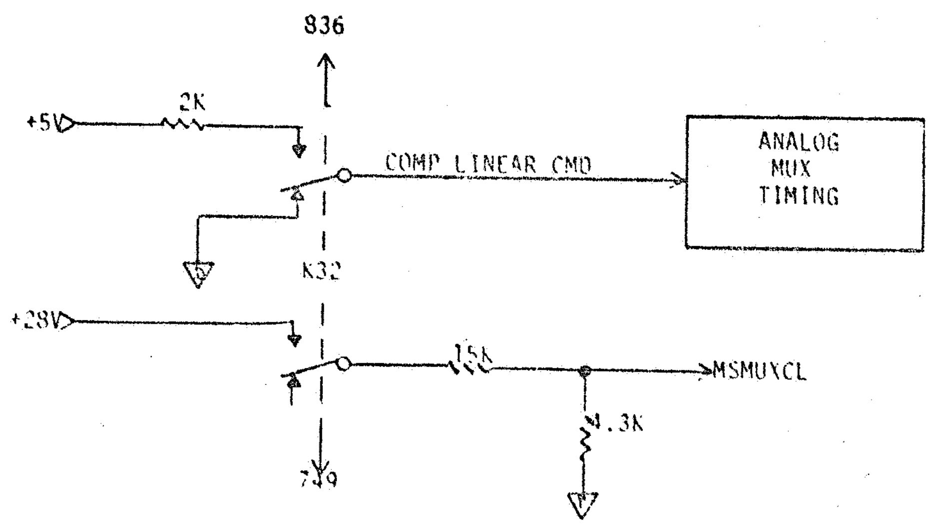


Figure 17.6-9. MUX Compression CMD CKT

17.6.1.34 (CMD 755) MIDSCAN CODE ON

Execution of the MIDSCAN Code on command (MSCON) causes the Multiplexer to insert MIDSCAN code in the video data stream in response to Scan Monitor Pulse #2. The MS code pre-empts 2000 words of video (data) in the serial data stream and consists of 100 black (zero level) words followed by 100 white (saturated level) words as in the end-of-line code. MSCON sets relay K31 (see Figure 17.6-10).

17.6.1.35 (CMD 842) MIDSCAN CODE OFF

Execution of the Midscan Code Off command (MSCOFF) inhibits the multiplexer response to the Midscan Monitor Pulse #2 such that no Midscan Code is generated. MSCOFF resets relay K31 (see Figure 17.6-10).

17.6.1.36 (CMD 832) Mode Operate

Execution of the mode operate command (MODEOPER) removes the scan mirror drive regulator inhibit clamp, connects the scan monitor circuit power regulators to the +16 VDC, -10 VDC lines and connects the multiplexer power converter to the -24.5 VDC line from the scanner. MODEOPER sets relays K25 and K28 and resets relay K23 (see Figures 17.6-8 and 17.6-11).

17.6.1.37 (CMD 751) Mode Launch

Execution of the Mode Launch Command (MODELNCH) inhibits the scan mirror drive regulator and disconnects the multiplexer from it's -24.5 VDC power source to reduce MSS power drain during launch. MODELNCH sets relay K33 and resets relay K28 (see Figure 17.6-11).

17.6.1.38 PDU/MSS Commands

The following commands to the Power Distribution Unit (PDU) control the redundant power inputs to the MSS and to the MSS support structure 15 watt heater on the IM.

1. (CMD) MSS A POWER ENABLE (ENMSSA)

   Execution of the "MSS A POWER ENABLE" command (ENMSSA) applies +28 VDC payload Bus A power through a 15 amp fuse to the MSS A load (see Paragraph 11.6).

2. (CMD) MSS B POWER ENABLE (ENMSSB)

   Execution of the "MSS B POWER ENABLE" command (ENMSSB) applies +28 VDC payload Bus B power through a 15 amp fuse to the MSS B load (see Paragraph 11.6).

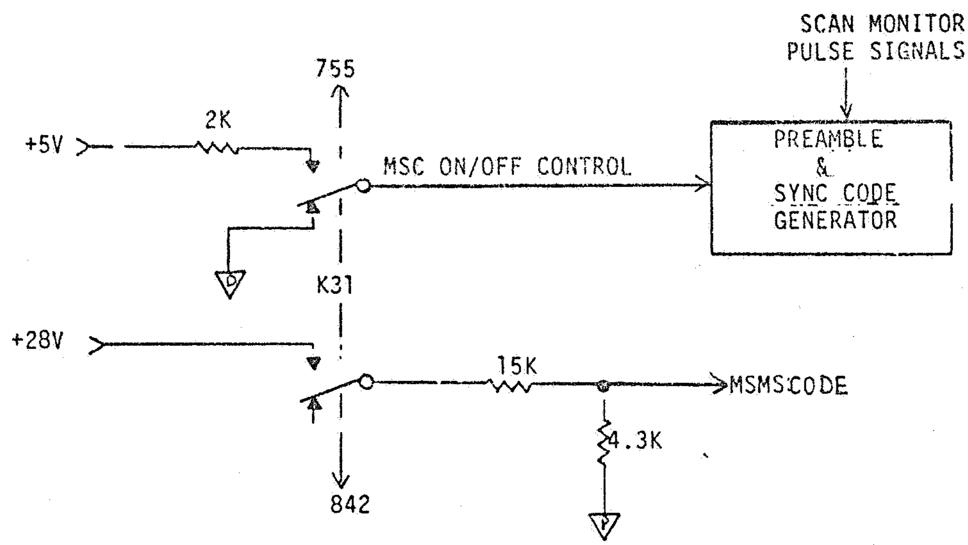
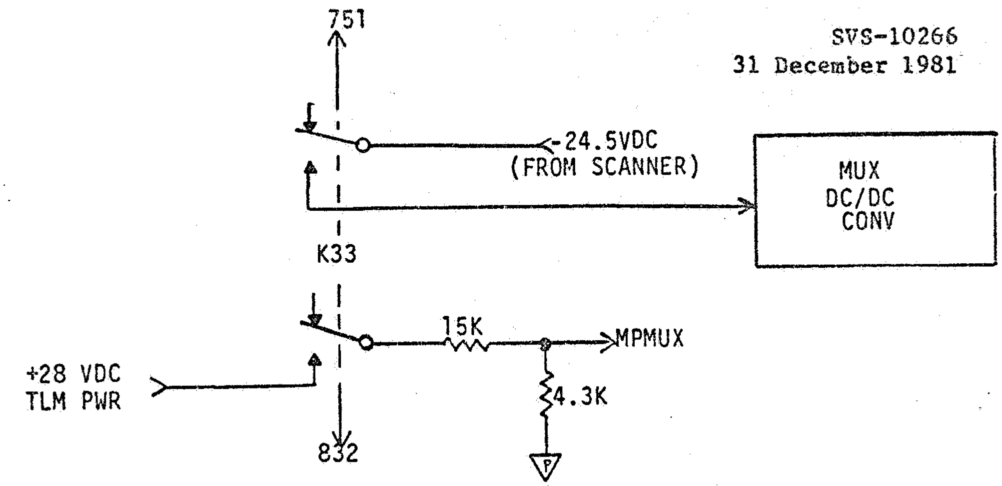


Figure 17.6-10. MID Scan Code



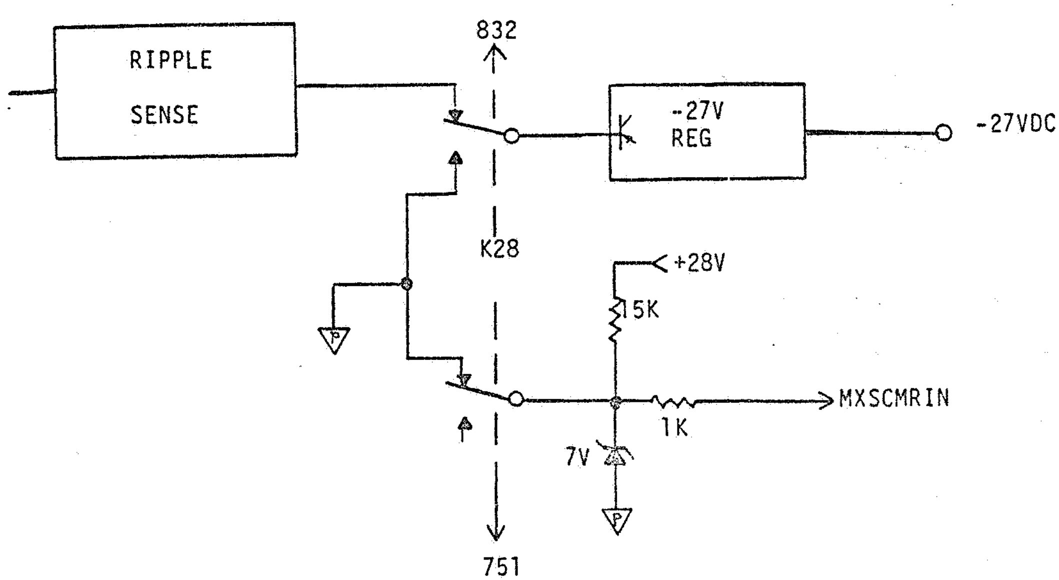


Figure 17.6-11. Mode Launch/Operate CMD CKTs (See also Figure 17.6-8)

3. MSS POWER DISABLE (DISMSS)

Execution of the "MSS POWER DISABLE" command (DISMSS) disconnects both +28 VDC payload Bus A and +28 VDC payload Bus B power from the MSS A and B loads (see Paragraph 11.6). The relays activated by this command are also activated by the "Payloads Off" command and are automatically activated when the FS enters the "safehold" mode.

4. DPU FULL ON (DPUON)

Execution of the "DPU FULL ON" command (DPUON) energizes the DPU which, in turn, generates time code and related format identifiers for strobing into the MSS Multiplexer.

5. DPU STANDBY (DPUSBY)

Execution of the "DPU STANDBY" command (DPUSBY) disables DPU generation of time coded and related format identifiers.

6. MSS INTERFACE HEATER B ENABLE (EMSSHTRB)

Execution of the "MSS INTERFACE HEATER B ENABLE" command (EMSSHTRB) applies either or both +28 VDC Bus A and +28 VDC Bus B through a 4 amp fuse to the MSS Interface B heaters located on the MSS support structure of the IM (See Paragraph 11.6).

7. MSS INTERFACE HEATER B DISABLE (DMSSHTRB)

Execution of the "MSS INTERFACE HEATER B DISABLE" command (DMSSHTRB) disconnects both +28 VDC Bus A and +28 VDC Bus B power from the MSS Interface B heaters (See Paragraph 11.6).

17.6.1.39 SCCU/MSS Commands

The following commands to the Spacecraft Command and Conditioning Unit (SCCU) control the power to and thermostat bypass of the MSS support structure 28 watt heater on the IM:

1. MSS INTERFACE PRIMARY HEATER A ENABLE (MSHAEN)

Execution of the "MSS INTERFACE PRIMARY HEATER A ENABLE" command (MSHAEN) applies +28 VDC bus (A or B) power to the MSS I/F primary heater via the SCCU heater module (A side) (see Paragraph 8.6).

2. MSS INTERFACE PRIMARY HEATER DISABLE (MSHADI)

   Execution of the "MSS INTERFACE PRIMARY HEATER A DISABLE" command (MSHADI) removes +28 VDC bus (A and B) power from the MSS I/F PRI HEATERS (See Paragraph 8.6).

3. MSS INTERFACE REDUNDANT HEATER ENABLE (MSHBEN)

   Execution of the "MSS INTERFACE REDUNDANT HEATER A ENABLE" command (MSHBEN) applies +28 VDC Bus (A or B) power to the MSS I/F REDUNDANT HEATER A via the SCCU heater module (B side) (see Paragraph 8.6).

4. MSS INTERFACE REDUNDANT HEATER DISABLE (MSHBDI)

   Execution of the "MSS INTERFACE REDUNDANT HEATER A DISABLE" command (MSHBDI) disconnects the 28 VDC Bus (A and B) power from the MSS I/F redundant A heaters (see Paragraph 8.6).

5. MSS INTERFACE HEATER THERMOSTAT BYPASS (MSTHBY)

   Execution of the "MSS INTERFACE HEATER THERMOSTAT BYPASS" command (MSTHBY) shunts the MSS I/F HEATER A mechanical thermostat for the MSS primary and redundant A heaters (see Paragraph 8.6).

6. MSS INTERFACE HEATER THERMOSTAT ENABLE (MSTHEN)

   Execution of the "MSS INTERFACE HEATER THERMOSTAT ENABLE" command (MSTHEN) opens the MSS I/F HEATER A mechanical thermostat bypass to the MSS primary and redundant A heaters (see Paragraph 8.6).

17.6.2 COMMAND SEQUENCES

17.6.2.1 MSS Prime (A) Configuration Sequence

This sequence configures the MSS and related PDU power input for Primary (System A) operation but does not turn the subsystem on. STOL procedure "PROC MSSPRIME" contains this command sequence and related status verification.

CMD No.	Acronym	Function
7,53	MSS,SYSOFF	SYSTEM POWER OFF
6,33	PDU,DISMSS	DISABLE MSS POWER (A&B)
6,03	PDU,ENMSSA	ENABLE MSS A POWER
8,32	MSS,MODEOPER	OPERATE MODE
8,42	MSS,MSCOFF	MID SCAN CODE OFF
8,36	MSS,MUXCOMP	MUX COMPRESSION MODE
7,19	MSS,SHDRON	ROTATING SHUTTER DRIVER ON
7,43	MSS,BD12LOGN	BANDS 1 & 2 LOW GAIN

8,12	MSS,BD1ON	BAND 1 LOW VOLTAGE ON
8,40	MSS,BD2ON	BAND 2 LOW VOLTAGE ON
8,54	MSS,BD3ON	BAND 3 LOW VOLTAGE ON
7,17	MSSBD4ON	BAND 4 VOLTAGE ON
7,05	MSS,BD1HVAON	BAND 2 HV A ON, HV B OFF
8,06	MSS,BD2HVAON	BAND 2 HV A ON, HV B OFF
7,11	MSS,BD3HVAON	BAND 3 HV A ON, HV B OFF
7,27	MSS,SHMONAON	SHUTTER MONITOR SOURCE A ON, B OFF
8,56	MSS,CALMPAON	CALIBRATION LAMP A ON, B OFF
7,31	MSS,SCMONAON	SCAN MONITOR SOURCE A ON, B OFF

17.6.2.2 MSS Redundant (B) Configuration Sequence

This sequence configures the MSS and related PDU power input for Redundant (System B) operation but does not turn the subsystem on. STOL procedure "PROC MSSREDUN" contains this command sequence and related status verification.

CMD No.	Acronym	Function
7,53	MSS,SYSOFF	SYSTEM POWER OFF
6,33	PDU,DISMSS	DISABLE MSS POWER (A&B)
6,03	PDU,ENMSSB	ENABLE MSS B POWER
8,32	MSS,MODEOPER	OPERATE MODE
8,42	MSS,MSCOFF	MID SCAN CODE OFF
8,36	MSS,MUXCOMP	MUX COMPRESSION MODE
7,19	MSS,SHDRON	ROTATING SHUTTER DRIVER ON
7,43	MSS,BD12LOGN	BANDS 1 & 2 LOW GAIN
8,12	MSS,BD1ON	BAND 1 LOW VOLTAGE ON
8,40	MSS,BD2ON	BAND 2 LOW VOLTAGE ON
8,54	MSS,BD3ON	BAND 3 LOW VOLTAGE ON
7,17	MSSBD4ON	BAND 4 VOLTAGE ON
7,35	MSS,BD1HVBON	BAND 1 HV B ON, HV A OFF
8,43	MSS,BD2HVAON	BAND 2 HV B ON, HV A OFF
7,39	MSS,BD3HVBON	BAND 3 HV B ON, HV A OFF
7,39	MSS,SHMONBON	SHUTTER MONITOR SOURCE B ON, A OFF
8,28	MSS,CALMPBON	CALIBRATION LAMP B ON, A OFF
7,33	MSS,SCMONBON	SCAN MONITOR SOURCE B ON, A OFF

17.6.2.3 MSS Prime (A) Turn-On Sequence

The following sequence turns the MSS On for operation using its primary power supply number 1. This sequence is normally used after the MSS has been configured in its PRIME (A) mode per Paragraph 17.6.2.1 above. The MSS A power must be enabled in the PDU prior to transmitting this sequence in order to energize MSS primary power supply number 1.

CMD No.	Acronym	Function
7,01	MSS,SYSAON	SYSTEM A POWER ON
8,58	MSS,HVON	SYSTEM HIGH VOLTAGE ON

17.6.2.4 MSS Redundant (B) Turn-On Sequence

The following sequence turns the MSS on for operation using its primary power supply number 2. This sequence is normally used after the MSS has been configured in its Redundant (B) mode per Paragraph 17.6.2.2 above. The MSS B power must be enabled in the PDU prior to transmitting this sequence in order to energize MSS primary power supply number 2.

CMD No.	Acronym	Function
8,62	MSS,SYSBON	SYSTEM B POWER ON
8,58	MSS,HVON	SYSTEM HIGH VOLTAGE ON

17.6.2.5 MSS Full Off Sequence

The following command sequence configures the MSS such that all commandable power functions are disabled and all power independent select functions are set to the Prime (A) state. This sequence will normally be included as the initial part of the launch mode command sequence. STOL procedure "PROC MSSFULOF" contains this command sequence and related MSS status verification.

CMD No.	Acronym	Function
7,53	/MSS,SYSOFF	SYSTEM POWER OFF
7,51	/MSS,MODELNCH	LAUNCH MODE (MUX OFF, SCAN INHIBITED)
7,09	/MSS,BD1HVOFF	BAND 1 HIGH VOLTAGE OFF
8,10	/MSS,BD2HVOFF	BAND 2 HIGH VOLTAGE OFF
7,23	/MSS,BD3HVOFF	BAND 3 HIGH VOLTAGE OFF
7,43	/MSS,BD12LOGN	BANDS 1 & 2 LOW GAIN
8,26	/MSS,BD1X4OFF	BANDS 1 THRU 4 LOW VOLTAGE OFF
8,14	/MSS,SHDROFF	ROTATING SHUTTER DRIVER OFF
7,27	/MSS,SHMONAON	SHUTTER MONITOR SOURCE A ON, B OFF
8,56	/MSS,CALMPAON	CALIBRATION LAMP A ON, B OFF
8,38	/MSS,CALMPOFF	CALIBRATION LAMP OFF
7,31	/MSS,SCMONAON	SCAN MONITOR SOURCE A ON, B OFF

7,07	/MSS,SCMONOFF	SCAN MONITOR OFF
8,42	/MSS,MSCOFF	MIDSCAN CODE OFF
8,36	/MSS,MUXCOMP	MUX COMPRESSION MODE
6,33	/PDU,DISMSS	DISABLE MSS POWER (A&B)

17.6.2.6 MSS Launch Mode Command Sequence

The following sequence configures the MSS in its launch mode sequence with the rotating shutter operating to prevent possible damage to the shutter motor bearings under vibrating environments. This sequence shall be used prior to exposing the MSS to vibration, shock, acoustic and launch environments.

CMD No.	Acronym	Function
PROC	MSSFULOF	MSS FULL OFF CONFIGURATION
7,19	MSS,SHDRON	ROTATING SHUTTER DRIVER ON
6,03	PDU,ENMSSA	ENABLE MSS A POWER
7,01	MSS,SYSAON	SYSTEM A POWER ON

17.6.3 COMMAND CONSTRAINTS

17.6.3.1 Launch Mode/Operating Mode

The MSS,SYSOFF command should be transmitted prior to transmitting the MSS,MODEOPER command to avoid a potential automatic power supply turn off when the MSS is configured in its launch mode. Violation of this constraint will cause no damage to the MSS.

17.6.3.2 System A/System B Power

The MSS,SYSOFF command shall be transmitted prior to transmitting either MSS,SYSAON or MSS,SYSBON commands and the PDU,DISMSS command shall be transmitted prior to transmitting either PDU,ENMSSA or PDU,ENMSSB commands in order to prevent energizing both MSS primary power supplies simultaneously. Violation of this constraint may damage the MSS.

17.6.3.3 High Voltage

The MSS,HVON command shall not be transmitted when the MSS is exposed to intermediate vacuum environments between normal atmospheric pressure and 10^{-5} torr. An outgassing period of ten hours at 10^{-5} torr or lower is required before energizing the high voltage power supplies in vacuum or space.

17.7 MSS TELEMETRY

MSS operation is monitored in the IM by 70 of 91 available telemetry channels. The monitored telemetry channels include 29 bilevel functions, 11 passive analog functions (temperature monitors) and 30 of the 51 active analog functions which include one (1) spare channel. All MSS telemetry channels are sampled once per major frame (approximately once every 16 seconds). The MSS telemetry functions monitored are listed in Table 17.7-1 and are described in Paragraphs 17.7.1 through 17.7.3. Similar descriptions of those PDU telemetry and SCCU functions pertinent to MSS operation are provided in Paragraphs 17.7.4 and 17.7.5, respectively. Limits for passive and active analog telemetry functions are given in Table 17.7-2.

17.7.1 MSS BILEVEL TELEMETRY

The functions in the MSS monitored by bilevel states are listed in TAble 17.7-1 under user identification (ID) numbers MSS-01, MSS-02, MSS-03 and MSS-04. The verification states are provided in Table 17.6-1 in the Command section. The bilevel telemetry acronyms are coded at the second character to distinguish between power switching, mode selection and all other functions as follows:

2nd Character	Function Type
P	Power (On/Off)
S	Mode Selection (A/B, High/Low, etc.)
X	All others

Example: MSMUXCL - MUX mode selection - compression/linear

17.7.1.1 System Power A On/Off (MPSYSA)

This telemetry monitors the power A ON/OFF status (see Figures 17.6-1 and 17.7-1). A logic "1" indicates the +21/35 VDC power from the spacecraft IM PDU is applied to primary power supply No. 1 (PPS-1). A logic "0" inidcates the +21/35 VDC power from the spacecraft IM PDU has been removed from PPS-1. The MSS power A must be enabled in the PDU to verify power is on when the System A On command executes.

17.7.1.2 System Power B On/Off (MPSYSB)

This telemetry monitors the power B On/Off status (see Figures 17.6-1 and 17.7-1). A logic "1" indicates the +21/35 VDC power from the spacecraft IM PDU has been applied to primary power supply No. 2 (PPS-2). A logic "0" means that the +21/35 volts DC power from the spacecraft IM PDU has been removed from PPS-2. The MSS power B must be enabled in the PDU to verify power is on when the System B On command executes.

Table 17.7-1. MSS Telemetry List

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MATRIX LOC(*) COL/ROW	MATRIX LOC(*) BIT	RIU-CH	REFERENCE PARAGRAPH
MSS-01	SYSTEM POWER A ON/OFF	MPSYSA	BI-LEVEL	96,00	BIT-1	07-65	17.7.1.1
	SYSTEM POWER B ON/OFF	MPSYSB		96,00	BIT-2	07-66	17.7.1.2
	ROTATING SHUTTER DRIVER ON/OFF	MPROTSHD		96,00	BIT-3	07-67	17.7.1.3
	CAL LAMP POWER ON/OFF	MPCALLP		96,00	BIT-4	07-68	17.7.1.4
	CAL LAMP A ON, B OFF/B ON, A OFF	MSCALLP		96,00	BIT-5	07-69	17.7.1.5
	SHUTTER MONITOR A ON, B OFF/B ON, A OFF	MSSHRMON		96,00	BIT-6	07-70	17.7.1.6
	SCAN MONITOR A ON, B OFF/B ON, A OFF	MSSCNMON		96,00	BIT-7	07-71	17.7.1.7
MSS-02	SCAN MIRROR INHIBITED/NORMAL	MXSCMRIN		97,00	BIT-0	08-32	17.7.1.8
	SCAN MONITOR ON/OFF	MPSCNMON		97,00	BIT-1	08-33	17.7.1.9
	MUX ON/OFF	MPMUX		97,00	BIT-2	08-34	17.7.1.10
	SCAN MIRROR POWER LINE 1 ON/OFF	MPSCMRL1		97,00	BIT-3	08-35	17.7.1.11
	SCAN MIRROR POWER LINE 2 ON/OFF	MPSCMRL2		97,00	BIT-4	08-36	17.7.1.12
	SCAN MIRROR POWER ON/OFF	MPSCMR		97,00	BIT-5	08-37	17.7.1.13
	MUX COMPRESSED/LINEAR	MSMUXCL		97,00	BIT-6	08-38	17.7.1.14
	MIDSCAN CODE OFF/ON	MSMSCODE		97,00	BIT-7	08-39	17.7.1.15
MSS-03	BAND 1 GAIN HIGH/LOW	MSBD1GHL		98,00	BIT-0	08-48	17.7.1.16
	BAND 2 GAIN HIGH/LOW	MSBD2GHL		98,00	BIT-1	08-49	17.7.1.17
	BAND 1 LOW VOLTAGE ON/OFF	MPBD1LV		98,00	BIT-2	08-50	17.7.1.18
	BAND 2 LOW VOLTAGE ON/OFF	MPBD2LV		98,00	BIT-3	08-51	17.7.1.19
	BAND 3 LOW VOLTAGE ON/OFF	MPBD3LV		98,00	BIT-4	08-52	17.7.1.20
	BAND 4 LOW VOLTAGE	MPBD4LV	BI-LEVEL	98,00	BIT-5	08-53	17.7.1.21

(*) MATRIX LOCATION SAME FOR BOTH MISSION & ENGINEERING FORMATS

Table 17.7-1. MSS Telemetry List (Continued)

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MATRIXLOC(*) COL/ROW	MATRIXLOC(*) BIT	RIU-CH	REFERENCE PARAGRAPH
MSS-04	HIGH VOLTAGE ON/OFF	MPSYSHV	BI-LEVEL	99,00	BIT-0	08-120	17.7.1.22
	BAND 1 HIGH VOLTAGE A ON/OFF	MPBD1HVA		99,00	BIT-1	08-121	17.7.1.23
	BAND 1 HIGH VOLTAGE B ON/OFF	MPBD1HVB		99,00	BIT-2	08-122	17.7.1.24
	BAND 2 HIGH VOLTAGE A ON/OFF	MPBD2HVA		99,00	BIT-3	08-123	17.7.1.25
	BAND 2 HIGH VOLTAGE B ON/OFF	MPBD2HVB		99,00	BIT-4	08-124	17.7.1.26
	BAND 3 HIGH VOLTAGE A ON/OFF	MPBD3HVA		99,00	BIT-5	08-125	17.7.1.27
	BAND 3 HIGH VOLTAGE B ON/OFF	MPBD3HVB		99,00	BIT-6	08-126	17.7.1.28
	SHUTTER ROTATING YES/NO	MXSHRROT	BI-LEVEL	99,00	BIT-7	08-127	17.7.1.29
MSS-05	SCAN MIRROR REGULATOR TEMP	MTSCMRRG	PASSIVE	33,06	N/A	08-17	17.7.2
MSS-06	SCAN MIRROR ELECTRONICS TEMP	MTSCMREL		33,07		08-18	17.7.2
MSS-07	SCAN MIRROR COIL TEMP	MTSCMRCL		33,08		08-19	17.7.2
MSS-08	SCAN MIRROR HOUSING TEMP	MTSCMRHG		33,09		08-20	17.7.2
MSS-09	MUX TEMP	MTMUX		33,10		08-21	17.7.2
MSS-10	PWR SUPPLY TEMP (RADIOMETER)	MTRADPS		33,11		08-22	17.7.2
MSS-11	ELECTRONICS COVER TEMP (RADIOMETER)	MTELCVR		33,12		08-23	17.7.2
MSS-12	PRIMARY POWER SUPPLY 1 TEMP	MTPPS1		33,13		08-80	17.7.2
MSS-13	PRIMARY POWER SUPPLY 2 TEMP	MTPPS2		33,14		08-81	17.7.2
MSS-14	FIBER OPTICS TEMP 1	MPFIBOP1		33,15		08-82	17.7.2
MSS-15	FIBER OPTICS TEMP 2	MTFIBOP2	PASSIVE	33,16		08-83	17.7.2
MSS-16	HV MONITOR BAND 1A	MVBD1HVA	ANALOG	33,17		08-112	17.7.3.1
MSS-17	HV MONITOR BAND 1B	MVBD1HVB		33,18		08-113	17.7.3.1
MSS-18	HV MONITOR BAND 2B	MVBD2HVA		33,19		08-114	17.7.3.1
MSS-19	HV MONITOR BAND 2B	MVBD2HVB		33,20		08-115	17.7.3.1
MSS-20	HV MONITOR BAND 3A	MVBD3HVA		33,21		08-116	17.7.3.1
MSS-21	HV MONITOR BAND 3B	MVBD3HVB		33,22		08-117	17.7.3.1
MSS-22	BAND 1 +/- 15V REGULATOR	MVBD1B15		33,23		08-40	17.7.3.2
MSS-23	BAND 2 +/- 15V REGULATOR	MVBD2B15	ANALOG	33,24	N/A	08-41	17.7.3.2

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Table 17.7-1. MSS Telemetry List (Continued)

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MATRIX LOC(*)		RIU-CH	REFERENCE PARAGRAPH
				COL/ROW	BIT		
MSS-24	BAND 3 +/- 15V REGULATOR	MVBD3B15	ANALOG	33,25	N/A	08-42	17.7.3.2
MSS-25	BAND 4 +/- 15V REGULATOR	MVBD4B15		33,26		08-43	17.7.3.2
MSS-26	+12V/-6V REGULATOR	MNP12NØ6		33,27		08-45	17.7.3.2
MSS-27	RADIOMETER +/- 19V	MVRADB19		33,29		08-47	17.7.4
MSS-28	RADIOMETER +19V	MVRADP19		33,28		08-46	17.7.5
MSS-29	MUX +5V LOGIC MONITOR	MVMUXPØ5		33,30		08-56	17.7.6
MSS-30	MUX A/D REFERENCE	MVMUXAD		33,31		08-57	17.7.7
MSS-31	AVERAGE DATA DENSITY	MXAVDATA		33,05		08-58	17.7.8
MSS-32	-24.5V PRIMARY POWER SUPPLY 1	MVPS1N24		33,33		08-104	17.7.3.9
MSS-33	-24.5V PRIMARY POWER SUPPLY 2	MVPS2N24		33,34		08-105	17.7.3.9
MSS-34	+5V RADIOMETER POWER SUPPLY	MVRADPØ5		33,35		08-108	17.7.10
MSS-35	BAND 1 CHANNEL A VIDEO	MXBD1CHA		33,39		08-96	17.7.11
MSS-41	BAND 2 CHANNEL A VIDEO	MXBD2CHA		33,45		08-97	17.7.11
MSS-47	BAND 3 CHANNEL A VIDEO	MXBD3CHA		33,51		08-98	17.7.11
MSS-53	BAND 4 CHANNEL A VIDEO	MXBD4CHA		33,57		08-99	17.7.11
MSS-	OPTICAL SWITCH LAMP 1 CURRENT MON	MIOPSWL1		33,37		08-106	17.7.12
MSS-60	OPTICAL SWITCH LAMP 2 CURRENT MON	MIOPSWL2		33,38		08-107	17.7.12
MSS-61	+15V TELEMETRY REGULATOR	MVTLMP15		33,32		08-109	17.7.13
MSS-62	CAL LAMP CURRENT	MICALLMP		33,25		08-110	17.7.14
MSS-63	SHUTTER CONTROL INTEGRATOR	MVSHRCTL		33,01		08-111	17.7.15
MSS-64	SCAN MIRROR DRIVE	MVSCMRDR		33,02		08-118	17.7.16
MSS-65	SCAN MIRROR REGULATOR	MVSCMRRG	ANALOG	33,03	N/A	08-119	17.7.17

NOTE: Ø INDICATES ZERO IN ACRONYMS

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Table 17.7-2. MSS Telemetry Limits

USER ID	ACRONYM	MODE	LIMITS UPPER EU	LIMITS UPPER COUNTS	LIMITS LOWER EU	LIMITS LOWER COUNTS	ENG UNITS (EU)	REFERENCE PARAGRAPH
MSS-05	MTSCMRRC	ALL	60	51	0	236	°C	17.7.2
MSS-06	MTSCMREL	ALL	60	51	0	236	°C	17.7.2
MSS-07	MTSCMRCL	ALL	82	24	0	236	°C	17.7.2
MSS-08	MTSCMRHG	ALL	50	67.5	0	236	°C	17.7.2
MSS-09	MTMUX	ALL	54	61	0	236	°C	17.7.2
MSS-10	MTRADPS	ALL	50	67.5	0	236	°C	17.7.2
MSS-11	MTELCVR	ALL	50	67.5	0	236	°C	17.7.2
MSS-12	MTPPS1	ALL	50	67.5	0	236	°C	17.7.2
MSS-13	MTPPS2	ALL	50	67.5	0	236	°C	17.7.2
MSS-14	MTFIBOP1	ALL	42	84	0	236	°C	17.7.2
MSS-15	MTFIBOP2	ALL	42	84	0	236	°C	17.7.2
MSS-16	MVBD1HVA	SYS&HV1AON	1.728	180	1.440	150	KV	17.7.3.1
	MVB1HVAO	SYS OR HV1AOFF	.029	3	0	0		
MSS-17	MVBD1HVB	SYS&HV1BON	1.728	180	1.440	150	KV	17.7.3.1
	MVB1HVBO	SYS OR HV1BOFF	.029	3	0	0		
MSS-18	MBVD2HVA	SYS&HV2AON	1.968	205	1.680	175	KV	17.7.3.1
	MVB2HVAO	SYS OR HV2AOFF	.029	3	0	0		
MSS-19	MVBD2HVB	SYS&HV2BON	1.968	205	1.680	175	KV	17.7.3.1
	MVB2HVBO	SYS OR HV2BOFF	.029	3	0	0		
MSS-20	MVBD3HVA	SYS&HV3AON	1.968	205	1.680	175	KV	17.7.3.1
	MVB3HVAO	SYS OR HV3AOFF	.029	3	0	0		

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Table 17.7-2. MSS Telemetry Limits (Continued)

USER ID	ACRONYM	MODE	LIMITS UPPER EU	LIMITS UPPER COUNTS	LIMITS LOWER EU	LIMITS LOWER COUNTS	ENG UNITS (EU)	REFERENCE PARAGRAPH
MSS-21	MVBD3HVB	SYS&HV3BON	1.970	205	1.681	175	KV	17.7.3.1
	MVB3HVBO	SYS OR HV3BOFF	.029	3	0	0		
MSS-22	MVBD1B15	SYS-ON	4.1	205	3.7	185	TMV	17.7.3.2
MSS-23	MVBD2B15	SYS-ON	4.1	205	3.7	185	TMV	17.7.3.2
MSS-24	MVBD3B15	SYS-ON	4.1	205	3.7	185	TMV	17.7.3.2
MSS-25	MVBD4B15	SYS-ON	4.2	210	3.7	185	TMV	17.7.3.2
MSS-26	MVP12NØ6	SYS-ON	4.2	210	3.8	190	TMV	17.7.3.2
MSS-27	MVRADB19	SYS-ON	3.9	195	3.1	155	TMV	17.7.4
MSS-28	MVRADP19	SYS-ON	22.0	250	17.6	200	V	17.7.5
	MVRDP190	SYS-OFF	.264	3	0	0		
MSS-29	MVMUXPØ5	SYS-ON	5.2	130	4.8	120	V	17.7.6
MSS-30	MVMUXAD	SYS-ON	3.6	180	3.4	170	V	17.7.7
MSS-32	MVPS1N24	SYS A ON	27.4	143	23.4	122	V	17.7.3.9
	MVPS1NO	SYS B ON	.58	3	0	0		
MSS-33	MVPS2N24	SYS B ON	27.4	143	23.4	122	V	17.7.3.9
	MVPS2NO	SYS A ON	.58	3	0	0		
MSS-34	MVRADPØ5	SYS-ON	5.1	255	4.7	235	V	17.7.10
MSS-61	MVTLMP15	SYS-ON	15.3	195	14.6	185	V	17.7.13
MSS-63	MVSHRCTL	SYS-ON	3.3	165	2.7	135	TMV	17.7.15
MSS-64	MVSCMRDR	SYS-ON	18.5	150	22.2	100	V	17.7.16
MSS-65	MVSCMRRG	SYS-ON	-27.0	126	-29.0	96	V	17.7.17
MSS-59	MIOPSWL1	SYS A ON	198	160	161	130	MA	17.7.12
	MIOPSW10	SYS B ON	3.72	3	0	0		

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Table 17.7-2. MSS Telemetry Limits (Continued)

USER ID	ACRONYM	MODE	LIMITS				ENG UNITS (EU)	REFERENCE PARAGRAPH
			UPPER		LOWER			
			EU	COUNTS	EU	COUNTS		
MSS-60	MIOPSWL2	SYS B ON	200	200	160	160	MA	17.7.12
	MIOPSW20	SYS A ON	3.33	3	0	0		
MSS-62	MICALLMP	SYS ON	102.5	205	97.5	195	MA	17.7.14
MSS-31	MXAVDATA	ALL	5.1	255	0	0	TMV	17.7.8
MSS-35	MXBD1CHA	SYS ON	4	172	0	130	V	17.7.11
MSS-41	MXBD2CHA	SYS ON	4	172	0	130	V	17.7.11
MSS-47	MXBD3CHA	SYS ON	4	172	0	130	V	17.7.11
MSS-53	MXBD4CHA	SYS ON	4	172	0	130	V	17.7.11

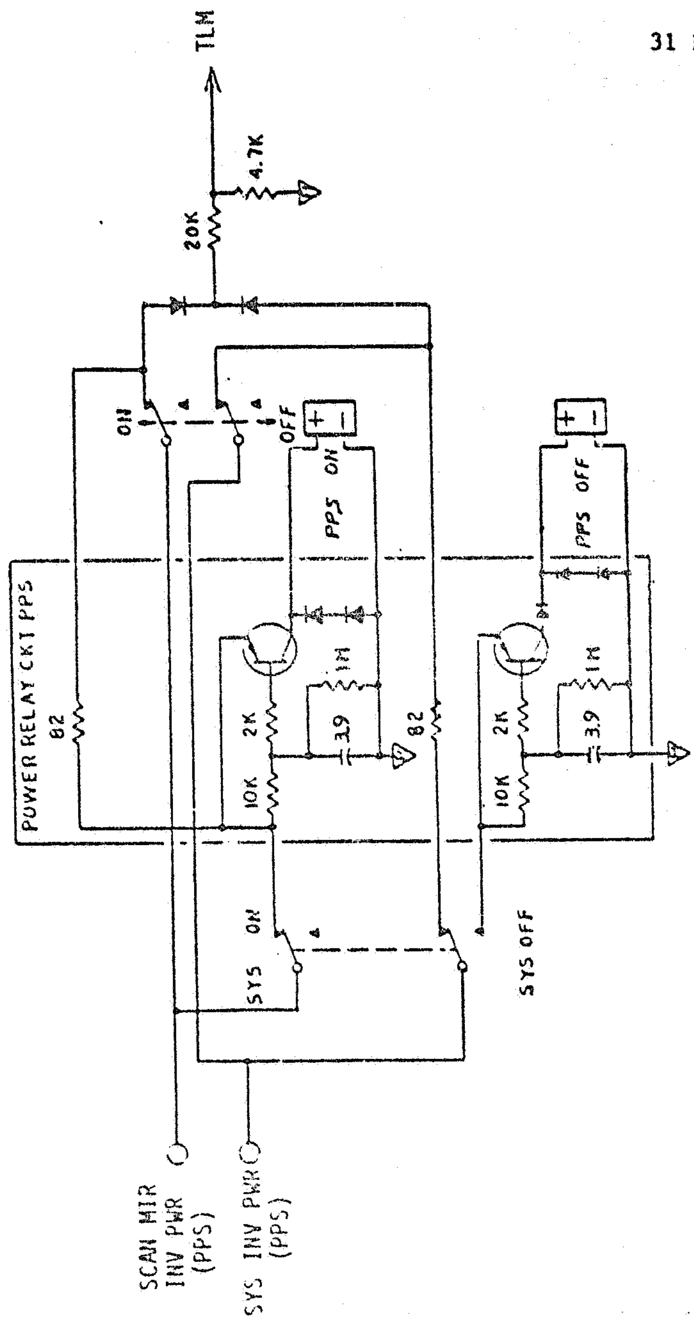


Figure 17.7-1. System Power On/Off Telemetry Circuit

CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MPSYSA MPSYSB

17.7.1.3 Rotating Shutter Driver On/Off (MPROTSHD)

This telemetry monitors the status of the Rotating Shutter. See Figures 17.6-5 and 17.7-2. A logic "1" indicates that -24.5 volts from the primary power supply has been appied to the rotating motor drive supply. A logic "0" indicates that the -24.5 volt input has been removed from the rotating shutter motor drive circuit.

17.7.1.4 Calibration Lamp Power On/Off (MPCALLP)

This telemetry monitors the Calibration Lamp Power On/Off status (see Figures 17.6-7 and 17.7-3). A logic "1" indicates that +9 VDC from the radiometer power supply has been applied to the calibration lamp driver. A logic "0" indicates that +9 VDC has been removed from the calibration lamp driver.

17.7.1.5 CAL Lamp A On, B Off/B On, A Off (MSCALLP)

This telemetry monitors the CAL Lamp A/B status (see Figures 17.6-7 and 17.7-2). A logic "1" indicates that calibration lamp A has been selected and logic "0" indicates that calibration lamp B has been selected.

17.7.1.6 Shutter Monitor A On, B Off/B On, A Off (MSSHRMON)

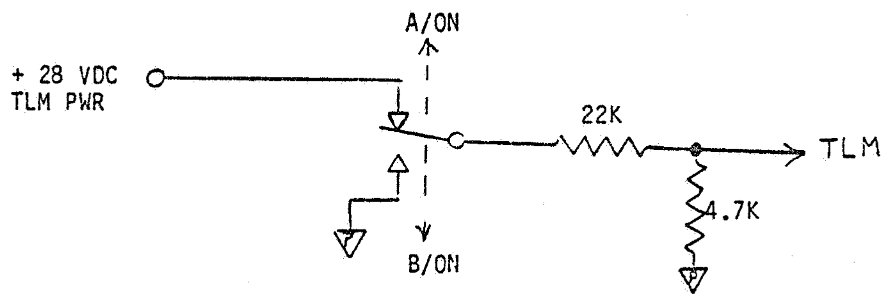
This telemetry monitors the shutter monitor A/B status (see Figures 17.6-6 and 17.7-3). A logic "1" indicates that +9 VDC LED drive from the radiometer supply has been applied to LED A and removed from LED B. A logic "0" indicates that 9 VDC LED drive has been applied to LED B and removed from LED A.

17.7.1.7 Scan Monitor A On, B Off/B On A Off (MSSCNMON)

This telemetry monitors the scan monitor source A/B status (see Figures 17.6-6 and 17.7-4). A logic 1 indicates that +9 VDC LED drive from the radiometer supply is applied to the scan monitor source A. A logic "0" indicates that +9 VDC LED drive is applied to source B and removed from source A.

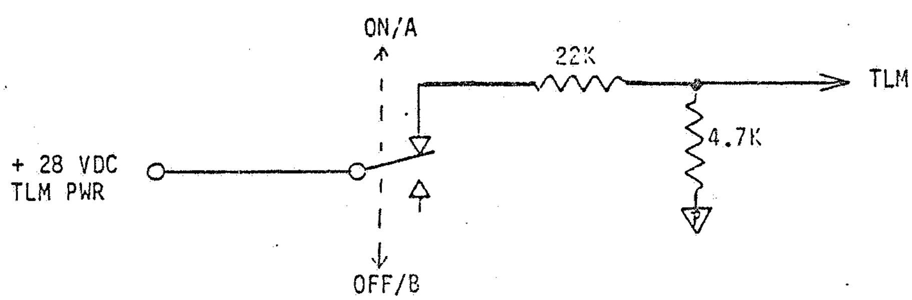
17.7.1.8 Scan Mirror Inhibited/Normal (MXSCMRIN)

This telemetry monitors the MODE OPERATE/MODE LAUNCH status (see Figures 17.6-11 and 17.7-5). A logic "1" removes the -27 VDC regulated output from the scan mirror regulator. A logic "0" provides a -27 VDC regulated output from the scan mirror regulator.



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:
MPROTSHD MSSHRMON

Figure 17.7-2. Shutter Monitor Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:
MPCALLP MSCALLP

Figure 17.7-3. CAL Lamp Telemetry Circuit

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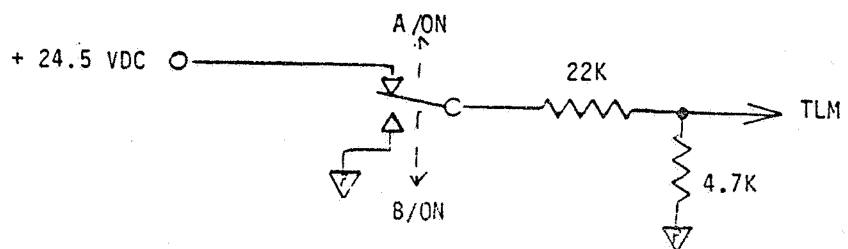
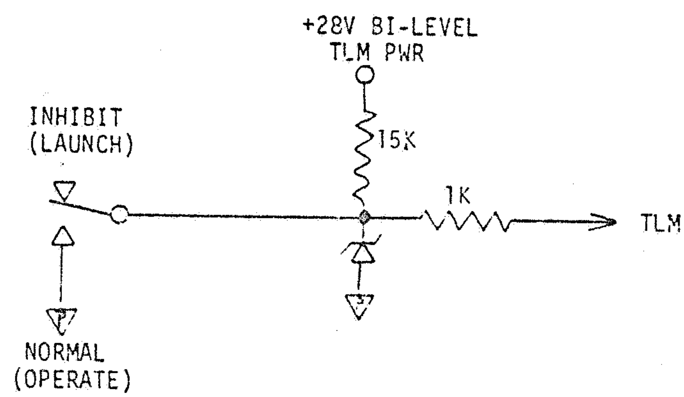


CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:
MSSCNMON

Figure 17.7-4. Scan Monitor Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:
MXSCMRIN

Figure 17.7-5. Scan Mirror Inhibit/Normal TLM Circuit

17.7.1.9 Scan Monitor On/Off (MPSCNMON)

This telemetry monitors the SCAN MONITOR ON/OFF status (see Figures 17.6-8 and 17.7-6). A logic "1" indicates that -10 VDC from the radiometer power supply is appleid to the scan monitor -6 VDC regulator which turns the scan monitor on. A logic "0" indicats that -10 VDC from the radiometer supply has been removed from the -6 VDC regulator, turning the scan monitor off.

17.7.1.10 Multiplexer On/Off (MPMUX)

This telemetry monitors the multiplexer ON/OFF (Mode Operate/Mode Launch) status (see Figures 17.6-11 and 17.7-7). A logic "1" indicates that -24.5 VDC from the primary power supply has been applied to the MUX DC/DC converter, turning the multiplexer on. A logic "0" indicates that -24.5 VDC has been removed from the multiplexer DC/DC converter.

17.7.1.11 Scan Mirror Power Line 1 (MPSCMRL1)

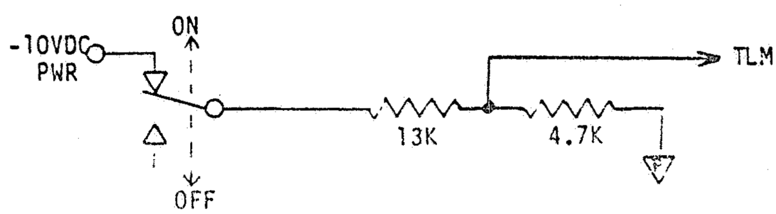
This telemetry monitors the SYSTEM POWER A/B status in the scan mirror (see Figures 17.6-1 and 17.7-8). A logic "1" indicates that -30 VDC line 1 has not been selected as the voltage source for the scan mirror drive circuitry. A logic "0" indicates that -30 VDC line 1 has been selected as the voltage source for the scan mirror drive circuitry. The inverted logic state (1 = Off, 0 = On) is derived by bucking the -30 VDC scan mirror power against the full time telemetry power (+28 VDC) supplied to the MSS whenever the spacecraft is powered.

17.7.1.12 Scan Mirror Power Line 2 On/Off (MPSCMRL2)

This telemetry monitors the SYSTEM POWER A/B status (see Figures 17.6-1 and 17.7-3). A logic "1" indicates that -30 VDC line 21 has not been selected as the voltage source for the scan mirror drive circuitry. A logic 0" indicates that -30 VDC line 2 has been selected as the voltage source for the scan mirror drive circuitry. The inverted logic state (1 = Off, 0 = On) is dervied in the same manner as described in 17.7.1.11 above.

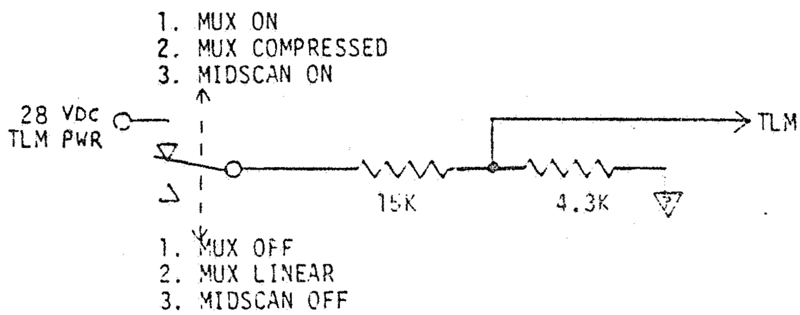
17.7.1.13 Scan Mirror Power On/Off (MPSCMR)

This telemetry monitors the scan mirror power line and detects the presence of the -30 VDC scan mirror power (see Figures 17.6-1 and 17.7-8). A logic "1" indicates that no voltage is on the scan mirror power line. A logic "0" indicates that -30 VDC is present on the power line. The inverted logic state (1 = Off, 0 = On) is derived in the same manner as described in 17.7.1.11 above.



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:
MPSCNMON

Figure 17.7-6. Scan Monitor On/Off



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MPMUX MSMUXCL MSMSCODE

Figure 17.7-7. MUX/Scanner Control TLM Circuit

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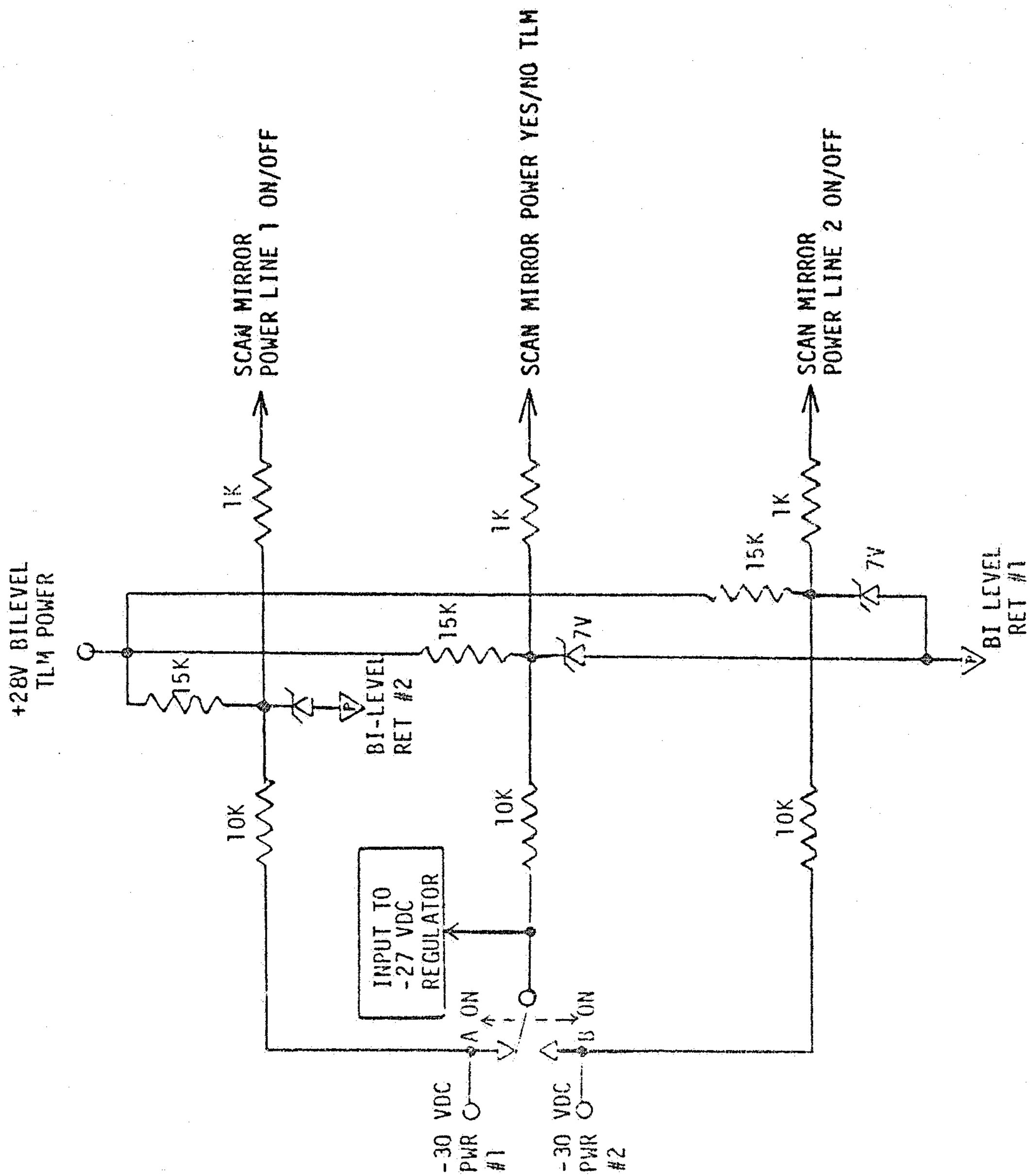


Figure 17.7-8. Scan Mirror Power TLM Circuit

CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MPSCMRL1 MPSCMRL2 MPSCMR

17.7.1.14 Multiplexer Compressed/Linear (MSMUXCL)

This telemtry monitors the MULTIPLEXER COMPRESSED/LINEAR mode status (see Figure 17.7-7 and 17.6-9). A logic "1" indicates that +5 VDC from the multiplexer DC to DC converter has been applied to the analog multiplexer causing the four segment, non-linear amplifier outputs to be selected for sampling by the analog multiplexer to effect the quasi logarithmic compression mode in bands 1, 2 and 3. A logic "0" indicates the linear amplifier outputs have been selected for sampling in these bands. Band 4 data is only sampled from a linear amplifier output.

17.7.1.15 Midscan Code Off/On (MSMSCODE)

This telemetry monitors the MIDSCAN CODE OFF/ON status (see Figure 17.6-10 and 17.7-7). A logic "1" indicates that +5 VDC from the multiplexer DC/DC converter has been applied to the appropriate input gate of the multiplexer preamble and sync code generator to inhibit midscan code generation in response to the midscan monitor pulse from the scanner. A logic "0" indicates that this input gate of the multiplexer preamble and sync code generator has been grounded causing the multiplexer to insert the midscan code in the video data in response to the midscan monitor pulse (SMP#2) from the scanner.

17.7.1.16 Band 1 Gain High/Low (MSBD1GHL)

This telemetry monitors the BAND 1 HIGH/LOW GAIN status (see Figures 17.6-4 and 17.7-9). A logic "1" indicates that -15 VDC has been applied to the Band 1 FET in the PMT buffer, causing the FET to open for a high gain output. A logic "0" indicates that +15 VDC has been applied to the Band 1 FET, causing the FET to short out the feedback resistor, reducing the gain output of Band 1 by a factor of 3.

17.7.1.17 Band 2 Gain High/Low (MSBD2GHL)

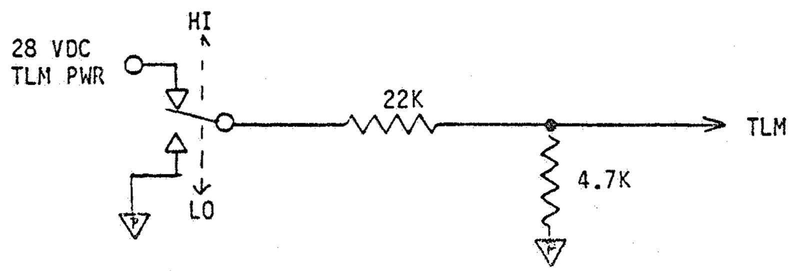
This telemetry monitor is identical to Band 1 Gain High/Low per 17.7.1.16 above (substitute Band 2 for Band 1 in the description).

17.7.1.18 Band 1 Low Voltage On/Off (MPBD1LV)

This telemetry monitors the Band 1 Low Voltage On/Off, Bands 1 to 4 status (see Figures 17.6-3 and 17.7-10). A logic "1" indicates that $\pm$19 VDC from the radiometer power supply has been applied to the Band 1 $\pm$15 volt regulators. A logic "0" indicates that the $\pm$19 VDC from the radiometer supply has been removed from the $\pm$15 V regulators, preventing Band 1 signal amplification.

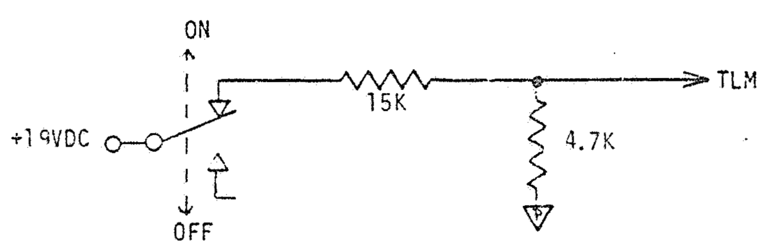
17.7.1.19 Band 2 Low Voltage On/Off (MPBD2LV)

This telemetry monitor is identical to Band 1 Low Voltage On/Off per 17.7.1.18 above (substitute Band 2 for Band 1 in the description).



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:
MSBD1GHL MSBD2GHL

Figure 17.7-9. Band 1, 2 Gain Hi/Lo TLM Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:
MPBD1LV MPBD2LV MPBD3LV MPBD4LV

Figure 17.7-10. Band 1, 2, 3, 4 Low Voltage On/Off TLM Circuit

17.7.1.20 Band 3 Low Voltage On/Off (MPBD3LV)

This telemetry monitor is identical to Band 1 Low Voltage On/Off per 17.7.1.18 above (substitute Band 3 for Band 1 in the description).

17.7.1.21 Band 4 Low Voltage On/Off (MPBD2LV)

This telemetry monitor is identical to Band 1 Low Votlage On/Off per 17.7.1.18 above (substitute Band 4 for Band 1 in the description).

17.7.1.22 High Voltage On/Off (MPSYSHV)

This telemetry monitors the HIGH VOLTAGE ON/OFF status (see Figures 17.6-2 and 17.7-11). A logic 1 indicates that 42 VAC from the radiometer supply is applied to selected Band 1 through Band 3 high voltage power supplies. One of the redundant (A or B) MSS high voltage power supplies in each of the Bands (1-3) must be enabled in order to operate. A logic "0" indicates that 42 VAC is not applied to the Band 1 through 3 high voltage power supplies.

17.7.1.23 Band 1 High Voltage A On/Off (MPBD1HVA)

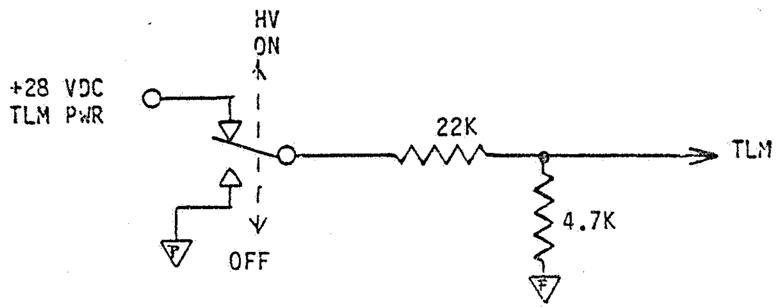
This telemetry monitors the Band 1 HIGH VOLTAGE A ON/OFF status (see Figure 17.6-2 and 17.7-12). A logic "1" indicates that high voltage power supply A has been selected to receive 42 VAC from the radiometer power supply assuming system high voltage is on. A logic "0" indicates that high voltage supply A has not been selected to receive 42 VAC in Band 1.

17.7.1.24 Band 2 High Voltage B On/Off (MPBD1HVB)

This telemetry monitors the Band 2 HIGH VOLTAGE B ON/OFF status (see Figures 17.6-2 and 17.7-12). A logic "1" indicates that high voltage supply B has been selected to receive 42 VAC from the radiometer supply assuming system high voltage is on. A logic "0" indicates that high voltage supply B has not been selected to receive 42 VAC in Band 1. A logic "0" concurrently in both MPBD1HVA and MPBD1HVB indicates Band 1 high voltage is off.

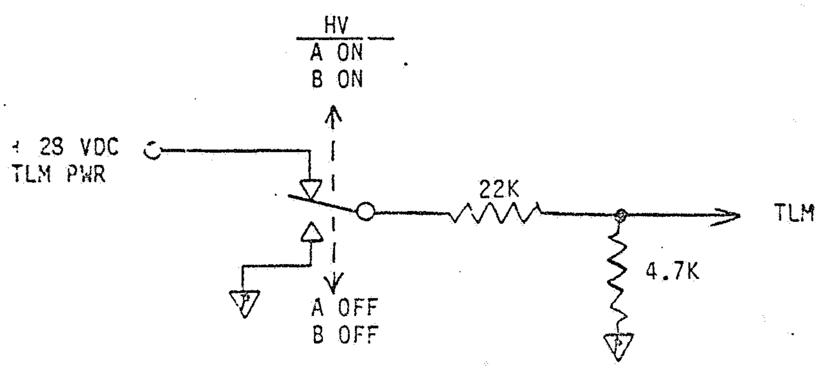
17.7.1.25 Band 2 High Voltage A On/Off (MPBD2HVA)

This telemetry monitors the Band 2 HIGH VOLTAGE A ON/OFF status (see Figure 17.6-2 and 17.7-12). A logic "1" indicates that high voltage supply A has been selected to receive 42 VAC from the radiometer supply assuming system high voltage is on. A logic "0" indicates that High Voltage supply A has not been selected to receive 42 VAC in Band 2.



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:
MPSYSHV

Figure 17.7-11. High Voltage On/Off TLM Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MPBD1HVA	MPBD2HVA	MPBD3HVA
MPBD1HVB	MPBD2HVB	MPBD3HVB

Figure 17.7-12. Band High Voltage A, On-Off/B, On-Off

17.7.1.26 Band 2 High Votlage B On/Off (MPBD2HVB)

This telemetry monitors the Band 2 HIGH VOLTAGE B ON/OFF status (see Figures 17.6-2 and 17.7-12). A logic "1" indicates that high voltage supply B has been selected to receive 42 VAC from the radiometer supply assuming system high voltage is on. A logic "0" indicates the high voltage supply B has not been selected to receive 42 VAC in Band 2. A logic "0" concurrently in both MPBD2HVA and MPBD2HVB indicates Band 2 high voltage is off.

17.7.1.27 Band 3 High Voltage A On/Off (MPBD3HVA)

This telemetry monitors the Band 3 HIGH VOLTAGE A ON/OFF status (see Figure 17.6-2 and 17.7-12). A logic "1" indicates that high voltage supply A has been selected to receive 42 VAC from the radiometer supply assuming system high voltage is on. A logic "0" indicates that high voltage A has not been selected to receive 42 VAC in Band 3.

17.7.1.28 Band 3 High Voltage B On/Off (MPBD3HVB)

This telemetry monitors the Band 3 HIGH VOLTAGE B ON/OFF status (see Figure 17.6-2 and 17.7-12). A logic "1" indicates that high voltage supply B has been selected to receive 42 VAC from the radiometer supply assuming system high voltage is on. A logic "0" indicates that high voltage supply B has not been selected to receive 42 VAC in Band 3. A logic "0" concurrently in both MPBD3HVA and MPBD3HVB indicates Band 3 high voltage is off.

17.7.1.29 Shutter Rotating Yes/No (MXSHRROT)

This telemetry monitors the presence or absence of the shutter sync signals from the shutter monitor preamplifier (see Figure 17.7-13). A logic "1" indicates that the shutter motor is rotating and shutter sync signals are generated. A logic "0" indicates that the shuttermotor is not rotating and no shutter sync signals are generated.

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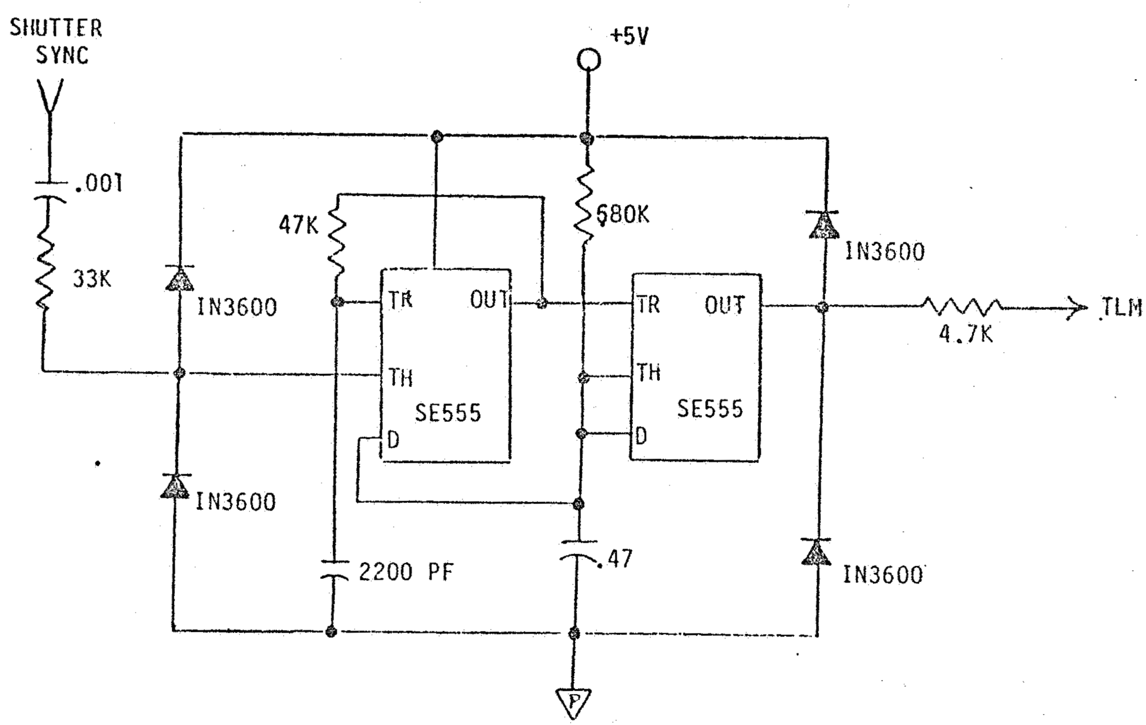


CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:
MXSHRROT

Figure 17.7-13. Shutter Rotating Yes/No Telemetry Circuit

17.7.2 PASSIVE ANALOG TELEMETRY

The following passive telemetry functions monitor temperatures in the MSS. Figure 17.7-14 shows the derivation circuit typical of each function. Note that the circuit is provided for information only; it is superseded by the exact circuit on the appropriate engineering drawing.

SCAN MIRROR REGULATOR TEMP	(MTSCMRRG)
SCAN MIRROR ELECTRONICS TEMP	(MTSCMREL)
SCAN MIRROR COIL TEMP	(MTSCMRCL)
SCAN MIRROR HOUSING TEMP	(MTSCMRHG)
MUX TEMP	(MTMUX)
PWR SUPPLY TEMP (RADIOMETER)	(MTTRADPS)
ELECTRONICS COVER TEMP (RADIOMETER)	(MTELCVR)
PRIMARY POWER SUPPLY 1 TEMP	(MTPPS1)
PRIMARY POWER SUPPLY 2 TEMP	(MTPPS2)
FIBER OPTICS TEMP 1	(MTFIBOP1)
FIBER OPTICS TEMP 2	(MTFIBOP2)

All passive analog telemetry functions in the MSS are temperature monitors. The temperatures are monitored using the 1 ma strobes from the RIU into thermistors (4K ohm at 25°C). The parallel 8.06K resistor serves to linearize the thermistor characteristic within the 0 to 5 volt telemetry readout voltage range. The temperature telemetry calibration curve is given in Appendix A.17, Figure A.17-1.

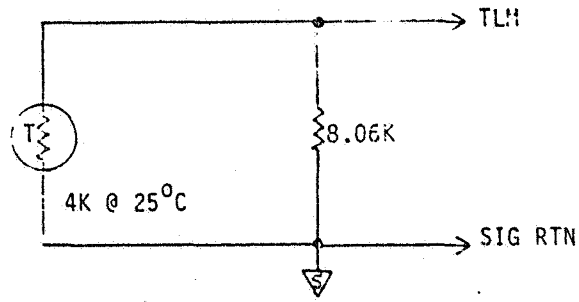
17.7.3 ACTIVE ANALOG TELEMETRY

The following are active analog telemetry functions in the MSS. Note that the derivation circuits are provided for information only; they are superseded by the exact circuit on the appropriate drawing.

17.7.3.1 <u>High Voltage Monitor Telemetry</u>

HIGH VOLTAGE MONITOR BAND 1A	(MVBD1HVA)
HIGH VOLTAGE MONITOR BAND 2A	(MVBD2HVA)
HIGH VOLTAGE MONITOR BAND 2B	(MVBD2HVB)
HIGH VOLTAGE MONITOR BAND 3A	(MVBD3HVA)
HIGH VOLTAGE MONITOR BAND 3B	(MVBD3HVB).

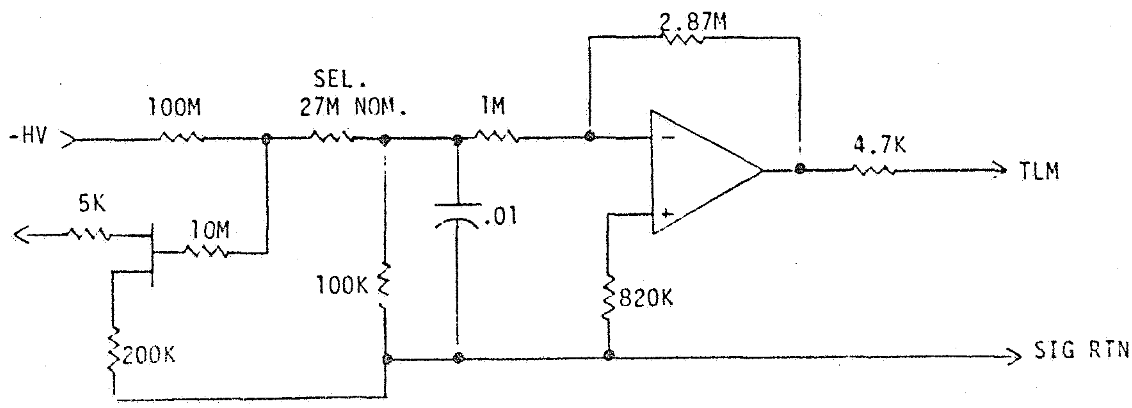
These telemetry functions are high voltage monitors (see Figure 17.7-15). The high voltage supplies which power the photomultiplier tubes for Bands 1, 2 and 3 are monitored by taking a small fraction of the negative high voltage and inverting it by means of an operational amplifier to provide the required positive voltage telemetry signal. The high voltage monitor calibration curve is given in Appendix A.17, Figure A.17-2.



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MTSCMRRG	MTSCMRHG	MTELCVR	MTFIBOP1
MTSCMREL	MTMUX	MTPPS1	MTFIBOP2
MTSCMRCL	MTRADPS	MTPPS2	

Figure 17.7-14. Passive Analog Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MVBD1HVA	MVBD2HVA	MVBD3HVA
MVBD1HVB	MVBD2HVA	MVBD3HVB

Figure 17.7-15. High Voltage TLM Circuit

17.7.3.2 +/-15 Volt Regulator Telemetry

BAND 1 ±15 VOLT REGULATOR (MVBD1B15)
BAND 2 ±15 VOLT REGULATOR (MVBD2B15)
BAND 3 ±15 VOLT REGULATOR (MVBD3B15)
BAND 4 ±15 VOLT REGULATOR (MVBD4B15)

These telemetry functions monitor the ±15 volt regulated output from the ±19 volt source (see typical Figure 17.7-16). The ±15 volt supplies for the amplifiers of each of the four spectral bands are regulated independently from the common ±19 volt source. When both positive and negative regulators are operating properly, the executed telemetry voltage range is 3.9 ±0.2 volts. No calibration curve is provided for the ±15 volt regulator telemetry.

17.7.3.3 +12/-6 Volt Regulator (MVP12N06)

This telemetry function monitors the +12/-6 VDC regulated outputs from their respective +16/-10 volt scan monitor power sources (see Figures 17.6-8 and 17.7-17). When both positive and negative regulators are operating properly the expected telemetry voltage range is 4.0 ±0.2 volts. No calibration curve is provided for the +12/-6 volt telemetry.

17.7.3.4 Radiometer +/-19 V (MVRADB19)

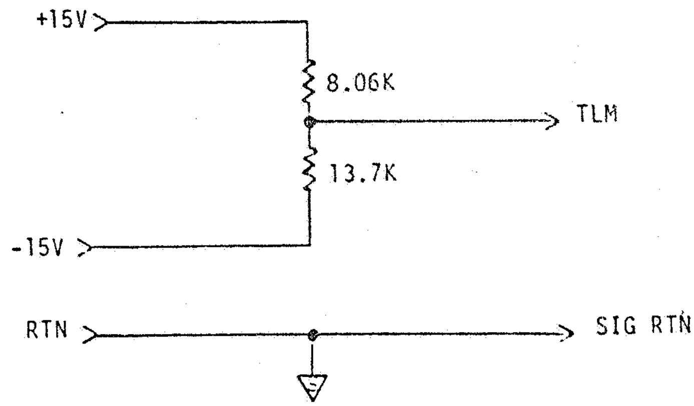
This telemetry monitors the ±19 VDC rectifier output (see Figures 17.6-1 and 17.7-18). When both supplies are operating properly a voltage of 3.5 ±.04 volts is expected. The expected telemetry range when both +19 and -19 volt rectifiers are operating properly is 3.5 ±0.4 volts. The ±19 volt telemetry characteristic is depicted in Appendix A.17, Figure A.17-3.

17.7.3.5 Radiometer +19 VDC (MVRADP19)

This telemetry monitors the +19 VDC rectifier output (see Figures 17.6-1 and 17.7-19). When the +19 VDC supply is operating properly, the expected telemetry voltage range is from 4 volts to 5 volts. The +19V telemetry calibration curve is given in Appendix A.17, Figure A.17-4.

17.7.3.6 MUX +5 Volt Logic Monitor (MVMUXP05)

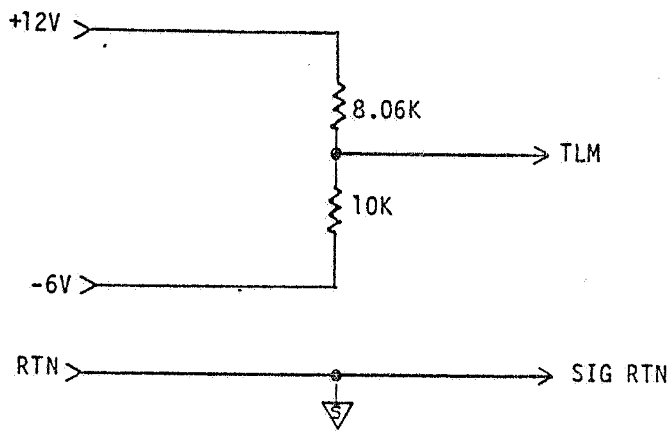
This telemetry monitors the +5 volt logic supply in the multiplexer (see Figure 17.7-20). The telemetry voltage is equal to one half of the multiplexer logic supply output. The expected telemetry range is from 2.4 V to 2.65 V. The +5 volt logic supply telemetry calibration curve is given in Appendix A.17, Figure A.17-5.



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MVBD1B15	MVBD3B15
MVBD2B15	MVBD4B15

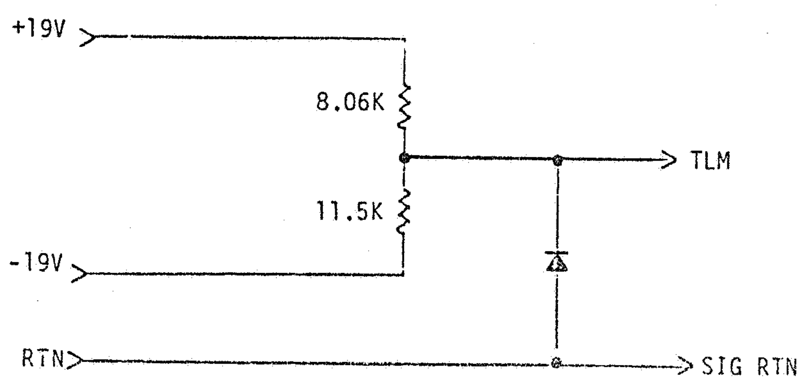
Figure 17.7-16. ±15 Volt Regulator Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVP12N06

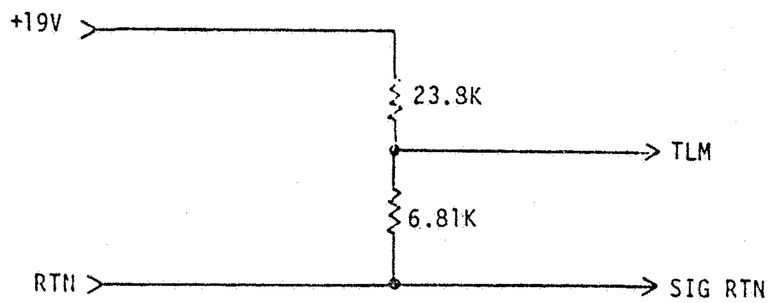
Figure 17.7-17. +12/-6 V Regulator Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVRADB19

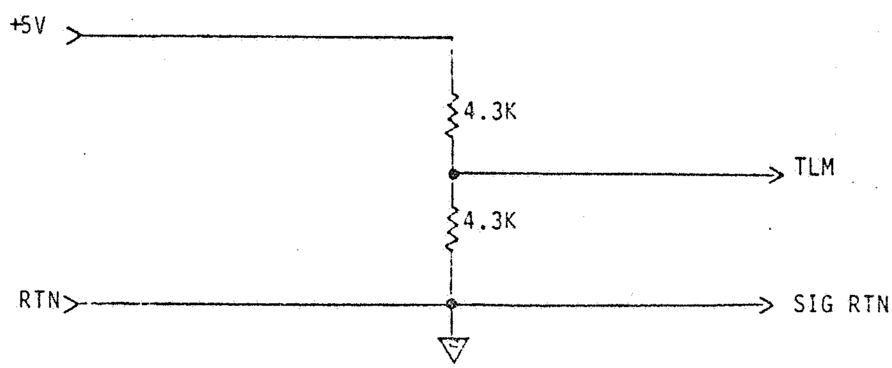
Figure 17.7-18. ±19 V Rectifier Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVRADP19

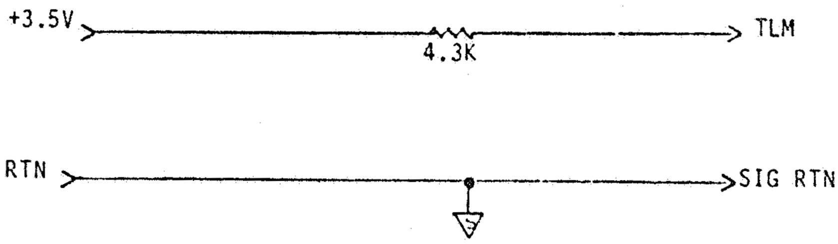
Figure 17.7-19. +19 V Rectifier Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVMUXP05

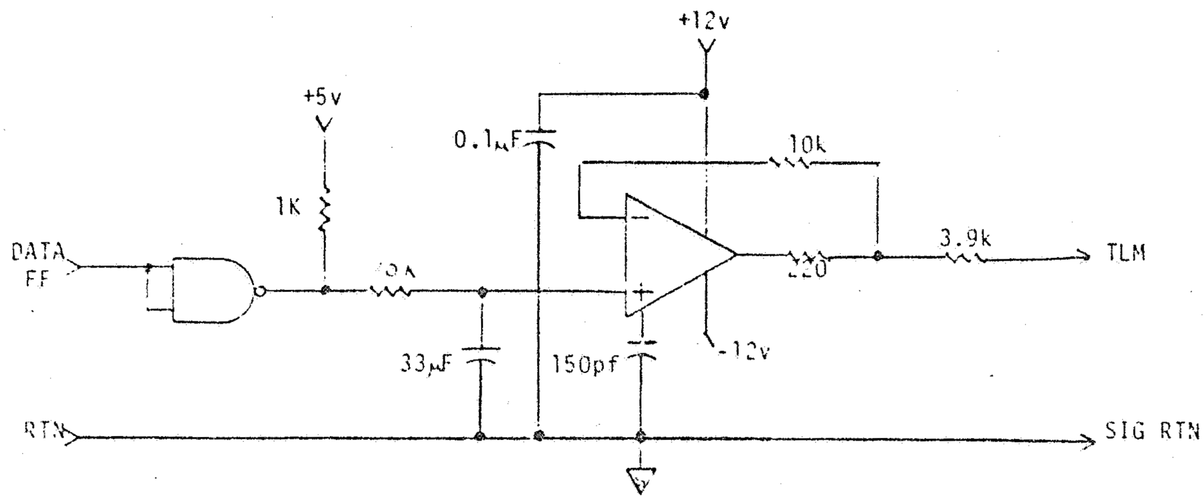
Figure 17.7-20. MUX +5 V Logic Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVMUXAD

Figure 17.7-21. MUX A/D Reference Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MXAVDATA

Figure 17.7-22. Average Data Density TLM Circuit

17.7.3.7 MUX A/D Reference (MVMUXAD)

This telemetry monitors the multiplexer analog to digital converter reference supply (see Figure 17.7-21). The telemetry voltage is equal to the A/D converter reference supply output. The expected telemetry range is from 3.4 volts to 3.6 volts. The MUX A/D reference supply telemetry calibration curve is given in Appendix A.17, Figure A.17-6.

17.7.3.8 Average Density of Data Transitions (MXAVDATA)

This telemetry monitors the average of data transitions density (see Figure 17.7-22). The telemetry represents the number of transitions, from "1" to "0" and "0" to "1", per unit time of the data bits. The telemetry voltage should vary between 0.5 volts and 4.7 volts when the MSS is powered in the normal mode indicating that the multiplexer is putting out data. No calibration curve is provided for the average density of data transitions.

17.7.3.9 -24.5 Volts Primary Power Supply Telemetry
-24.5 VDC Primary Power Supply 1 (MVPS1N24)
-24.5 VDC Primary Power Supply 2 (MVPS2N24)

These telemetry functions monitor the -24.5 VDC outputs of primary power supplys one and two (see Figure 17.7-23). The expected telemetry range for PPS1 and PPS2 -24.5 volt outputs is from 2.35 volts to 2.74 volts when energized. The calibration curve for the -24.5 volt supplies is given in Appendix A.17, Figure A.17-7.

17.7.3.10 +5 V Radiometer Supply (MVRADP05)

This telemetry monitors the +5 volt radiometer supply output (see Figure 17.7-24). The 4.7K isolation resistor is used as a source impedance to the RIU. The telemetry voltage is equal to the +5 V radiometer supply output. The expected telemetry voltage range is from 4.7 volts to 5.1 volts. The +5V radiometer supply telemetry calibration curve is given in Appendix A.17, Figure A.17-8.

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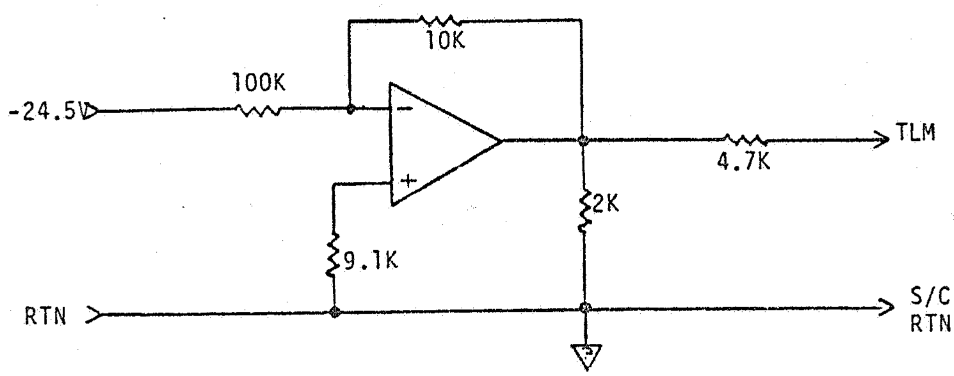
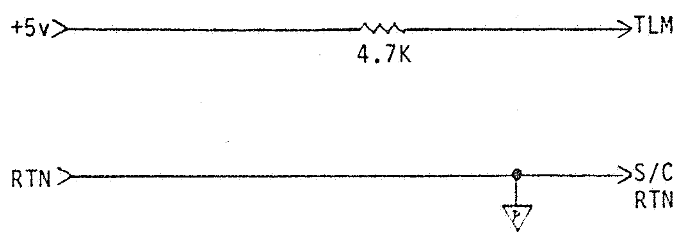


CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MVPS1N24
MVPS2N24

Figure 17.7-23. -24.5 V PPS Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVRADP05

Figure 17.7-24. +5 V Radiometer Power Supply TLM Circuit

17.7.3.11 Bands 1 to 4 Video Channel Telemetry

Band 1 Channel A Video	(MXBD1CHA)
Band 2 Channel A Video	(MXBD2CHA)
Band 3 Channel A Video	(MXBD3CHA)
Band 4 Channel A Video	(MXBD4CHA)

These telemetry functions monitor the Bands 1 to 4 video channel analog telemetry (see Figure 17.7-25). The telemetry provides a method for isolating a sensor channel failure to either the scanner or the multiplexer in the event of a fault. Since a sensor channel failure can be identified from demultiplexed video data and the quality of the telemetry as sampled every 16 seconds is poor, only 1 sensor per band is monitored in the spacecraft to permit band isolation of a fault condition. Sensors 1, 7, 13 and 19 are monitored. The video output telemetry calibration curve is given in Appendix A.17, Figure A.17-9.

17.7.3.12 Optical Switch Lamp Current Monitor

Optical Switch Lamp 1 Current Monitor	(MIOPSWL1)
Optical Switch Lamp 2 Current Monitor	(MIOPSWL2)

These telemetry functions monitor the current in the Scan Mirror assembly optical switch lamp power lines (see Figure 17.7-26). The expected range of the optical switch lamp current for both PPS1 and PPS2 is 160 ma to 200 ma.

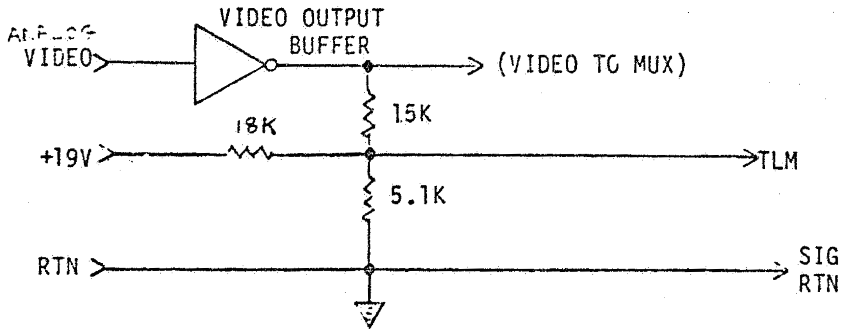
A different resistance value is used to generate the telemetry signal in PPS2 so its calibration curve is different from that of PPS1. The telemetry voltage range is from 2.6 to 3.3 volts for MIOPSWL1 and from 3.2 to 4.0 volts for MIOPSWL2. The telemetry calibration curves are given in Appendix A.17, Figures A.17-10 and A.17-11, respectively.

17.7.3.13 +15 V Telemetry Regulator (MVTLMP15)

This telemetry monitors the +15 VDC telemetry voltage regulator (see Figure 17.7-27). The expected telemetry voltage is 3.8 $\pm$.01 volts. The +15 volt telemetry regulator telemetry calibration curve is given in Appendix A.17, Figure A.17-12.

17.7.3.14 CAL Lamp Current (MICALLMP)

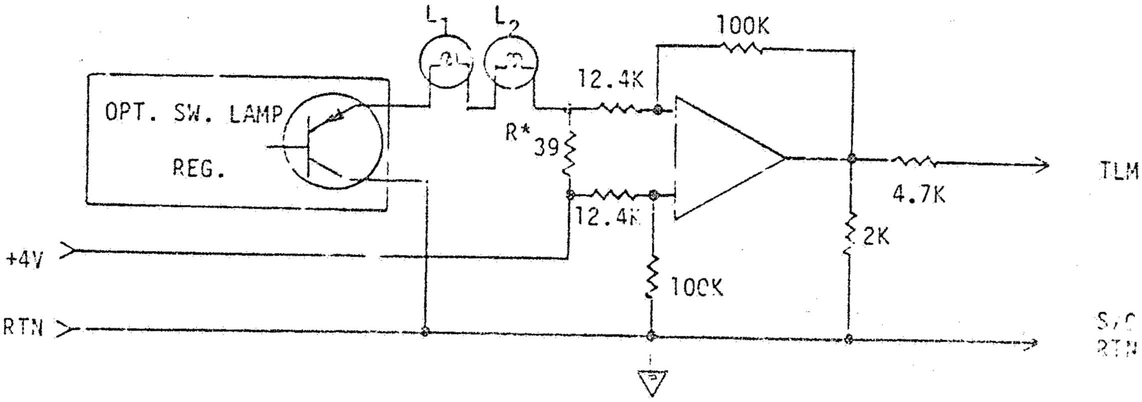
This telemetry monitors the calibration lamp current (see Figure 17.7-28). The expected calibration lamp current range is from 85 ma to 110 ma. The corresponding telemetry voltage range is from 3.4 to 4.4 volts. The cal lamp current telemetry calibration curve is given in Appendix A.17, Figure A.17-13.



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MXBD1CHA MXBD3CHA
MXBD2CHA MX2D4CHA

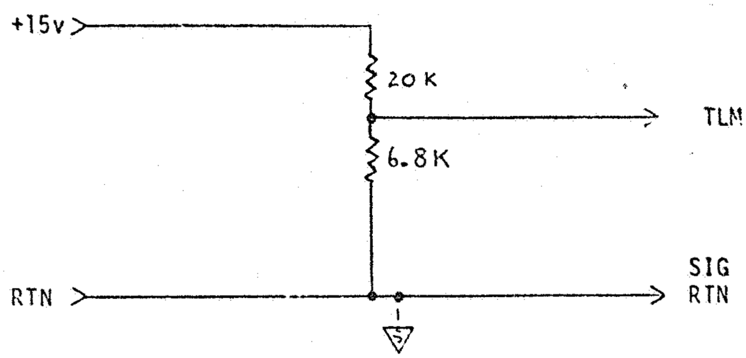
Figure 17.7-25. Video Channel Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:
MIOPSWL1
MIOPSWL2

*R39 = 2.0 in PPS-1
2.5 in PPS-2

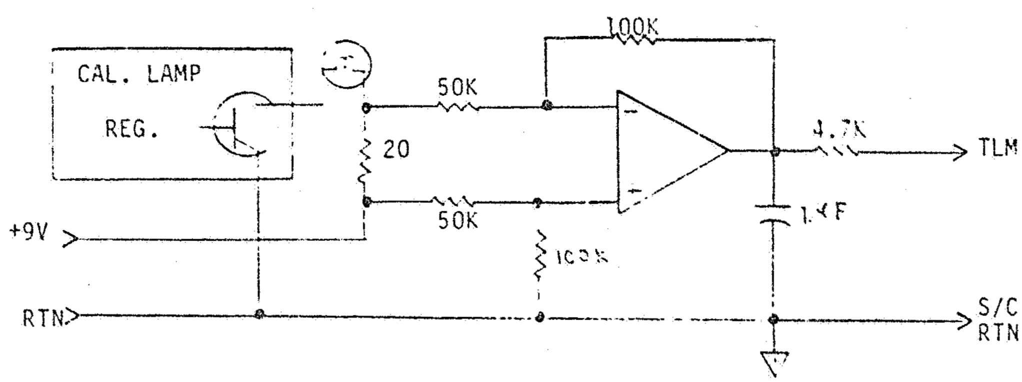
Figure 17.7-26. Optical Switch Lamp Current Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVTLMP15

Figure 17.7-27. +15 Volt Regulator TLM Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MICALLMP

Figure 17.7-28. CAL Lamp Current Telemetry Circuit

17.7.3.15 Shutter Control Integrator (MVSHRCTL)

This telemetry monitors the input voltage from the control integrator in the shutter motor synchronization loop (see Figure 17.7-29). The voltage developed depends on the motor speed as well as the individual motor constants. For the Protoflight MSS the nominal telemetry voltage is 3 $\pm$0.3 volts at 408.6 RPM.

17.7.3.16 Scan Mirror Drive (MVSCMRDR)

This telemetry monitors the scan mirror drive square wave after rectification and filtering (see Figure 17.7-30). The expected telemetry voltage range is from 2.0 V to 3.0 V. The scan mirror drive telemetry calibration curve is given in Appendix A.17, Figure A.17-14.

17.7.3.17 Scan Mirror Regulator (MVSCMVRRG)

This telemetry monitors the scan mirror drive voltage regulator output (see Figure 17.7-31). The expected scan mirror regulator output telemetry is 2.50 volts. The scan mirror regulator telemetry calibration curve is given in Appendix A.17, Figure A.17-15.

17.7.4 PDU/MSS TELEMETRY

The following bilevel telemetry functions located in the PDU are pertinent to MSS operation and thermal control.

17.7.4.1 MSS POWER A ENA/DIS (YMSAPWR)

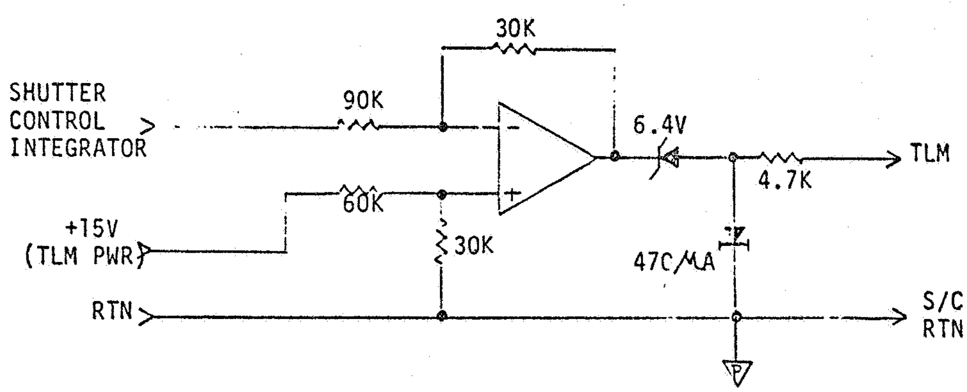
This telemetry monitors the +28 volt payload Bus A from the PDU to the MSS (Reference Paragraph 11.7). A "1" state indicates the +28 volt Payload Bus A is connected to the MSS-A Load and a "0" state indicates the +28 volt Payload Bus A is disconnected from the MSS-A load.

17.7.4.2 MSS POWER B ENA/DIS (YMSBPWR)

This telemetry monitors the +28 volt payload Bus B from the PDU to the MSS (Reference Paragraph 11.7). A "1" state indicates the +28 volt payload Bus B is connected to the MSS B load and a "0" state indicates the +28 volt paylod Bus B is disconnected from the MSS B load.

17.7.4.3 MSS INTERFACE B HEATER ENA/DIS (YMSBHTR)

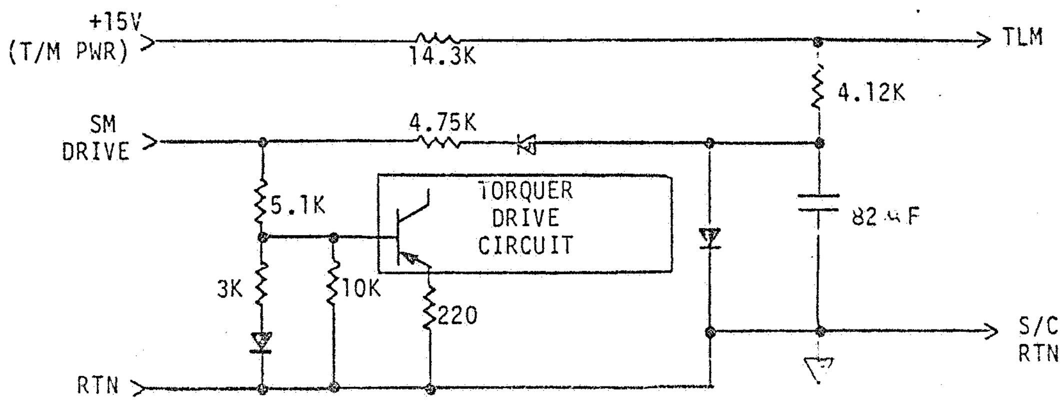
This telemetry monitors the application of the +28 volts Bus A and Bus B to the MSS IF B heaters located on the MSS support structure of the IM (Reference Paragraph 11.7). A "1" state indicates that either or both the +28 volt Bus A and +28 volt Bus B have been applied to the MSS interface B heaters. A "0" state indicates that both +28 volt Bus A and +28 volt Bus B have been disconnected from the heaters.



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVSHRCTL

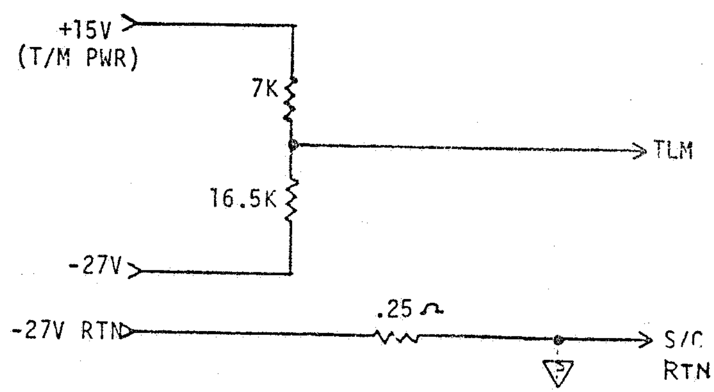
Figure 17.7-29. Shutter Control Integrator Telemetry Circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTIONS:

MVSCMRDR

Figure 17.7-30. Scan Mirror Drive Telemetry circuit



CIRCUIT APPLIES TO THE FOLLOWING FUNCTION:

MVSCMRRG

Figure 17.7-31. Scan Mirror Regulator Telemetry Circuit

17.7.5 SCCU/MSS TELEMETRY

The following bilevel to telemetry functions located in the SCCU are pertinent to MSS thermal control.

17.7.5.1 MSS Interface A Primary Heater ENA/DIS (UMSAHTA)

This telemetry monitors the application of +28 VDC bus (A or B) power to the MSS IF A Primary Heater located on the MSS support structure of the IM through the SCCU heater module (Reference Paragraph 8.6). A "1" state indicates the application of +28 VDC bus power to the MSS IF A primary heater and a "0" state indicates the power has been removed.

17.7.5.2 MSS Interface A Redundant Heater ENA/DIS (UMSAHTB)

This telemetry monitors the application of +28 VDC bus (A or B) power to the MSS IF A Redundant Heater through the SCCU heater module (Reference Paragraph 8.6). A "1" state indicates the application of +28 V bus power to the MSS IF A redundant heater and a "0" state indicates the power has been removed.

17.7.5.3 MSS Interface A Heater THermostate Bypass/ENA (UMSTATHT)

This telemetry monitors the use of the MSS IF A Heater Thermostat (reference Paragraph 8.6). A "1" state indicates the MSS IF A mechanical thermostat has been bypassed. A "0" state indicates the thermostat is controlling the heater.

18.0 PAYLOAD CORRECTION DATA

SECTION 18.0

PAYLOAD CORRECTION DATA

The operation of the Landsat-D payloads (MSS and TM) induces vibration or jitter into the imaging instruments. In order to correct this jitter, Payload Correction Data (PCD) is generated by the Payload Correction Data Subsystem and downlinked where it may be used in the IGF to correct TM images.

18.1 PCD FUNCTIONAL DESCRIPTION

The PCD subsystem, as shown in Figure 18.1-1, consists of an Angular Displacement Sensor (ADS), ADS Electronics and a PCD Formatter. The PCD Formatter is located in the Power Distribution Unit (PDU).

18.1.1 ANGLE DISPLACEMENT SENSOR (ADS)

The ADS monitors Thematic Mapper (TM) angular motion, specifically angular displacement of the TM mounted on the flight segment (FS) resulting from the reaction of the TM oscillating mirror.

The ADS consists of three fluid rotor angular displacement sensors configured in a tri-axial arrangement. A block diagram of one of the fluid rotor sensors is shown in Figure 18.1-2. These sensors are mounted on the TM and provide input to the ADS electronics.

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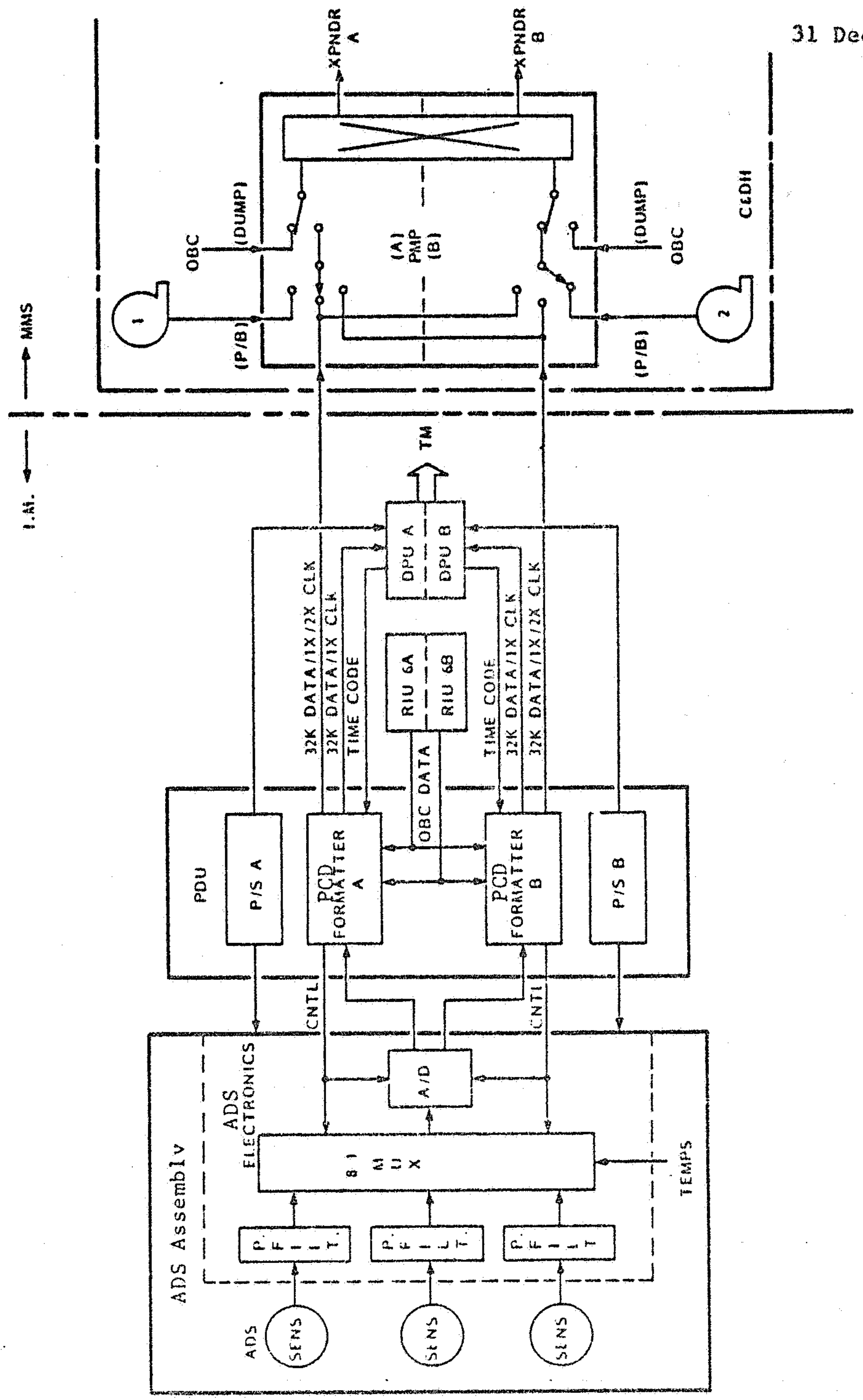
31 December 1981



LSD-WPC-263

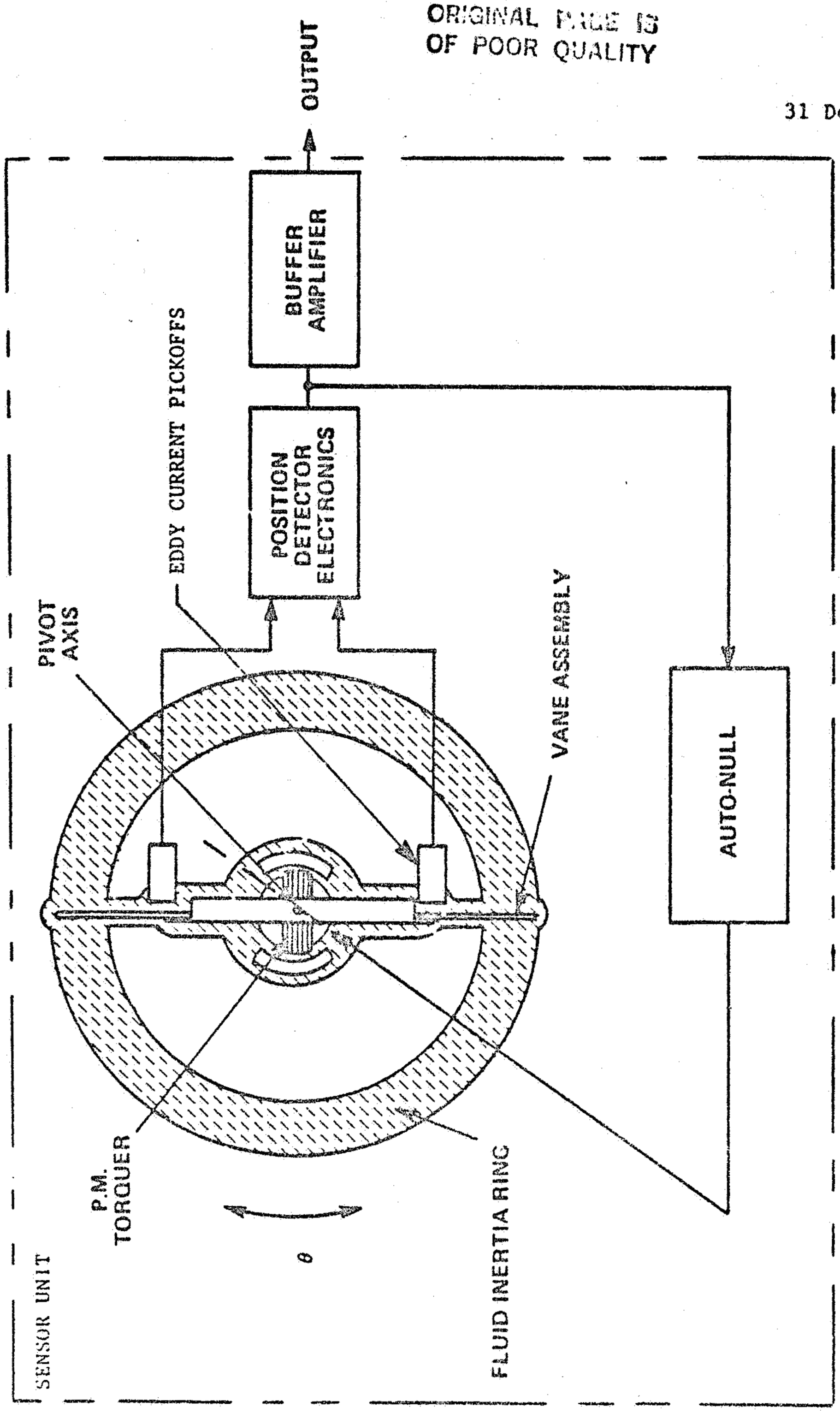


Figure 18.1-2. Angular Displacement Sensor

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18.1.2 ADS ELECTRONICS

The ADS electronics processes the ADS outputs into a form usable by the Formatter electronics. The functions provided are:

1. Filters - each ADS axis signal is low-pass filtered to eliminate higher frequency components that would lead to biasing in the sampled, digitized data.

2. Temperature Sensor Conditioning Circuits - these circuits provide the current and reference to read the temperature sensors.

3. Analog Multiplexer - the analog multiplexer selects one of eight possible analog inputs. Three of these inputs are the ADS axis inputs, four are the temperature inputs, and one input is used in monitoring the A/D converter.

4. A/D Converter - converts the selected analog input into a digitized output.

A block diagram of the ADS electcrnics is shown in Figure 18.1-3. The ADS interfaces only to the ADS electronics; therefore, the ADS power and the ADS test signals are interfaced via the ADS electronics.

18.1.2.1 Analog Multiplexer

The analog multiplexer selects one of eight possible inputs, as determined by select signals, and presents the signal to the A/D converter for digitizing as shown in Figure 18.1-3. The inputs are:

1. X-axis ADS data
2. Y-axis ADS data
3. Z-axis ADS data
4. X-axis ADS temperature data
5. Y-axis ADS temperature data
6. Z-axis ADS temperature data
7. ADS electronics temperature
8. A/D converter monitor

18.1.2.2 Analog to Digital Converter

The signal selected by the multiplexer is analog to digital converted and sent to the PCD Formatter via serial signal. Inputs to the A/D converter are the data signals, the 512 Hz clock and start conversion signal. Serial data signals and the end of conversion (EOC) signal are outputted to both PCD Formatter A and B.

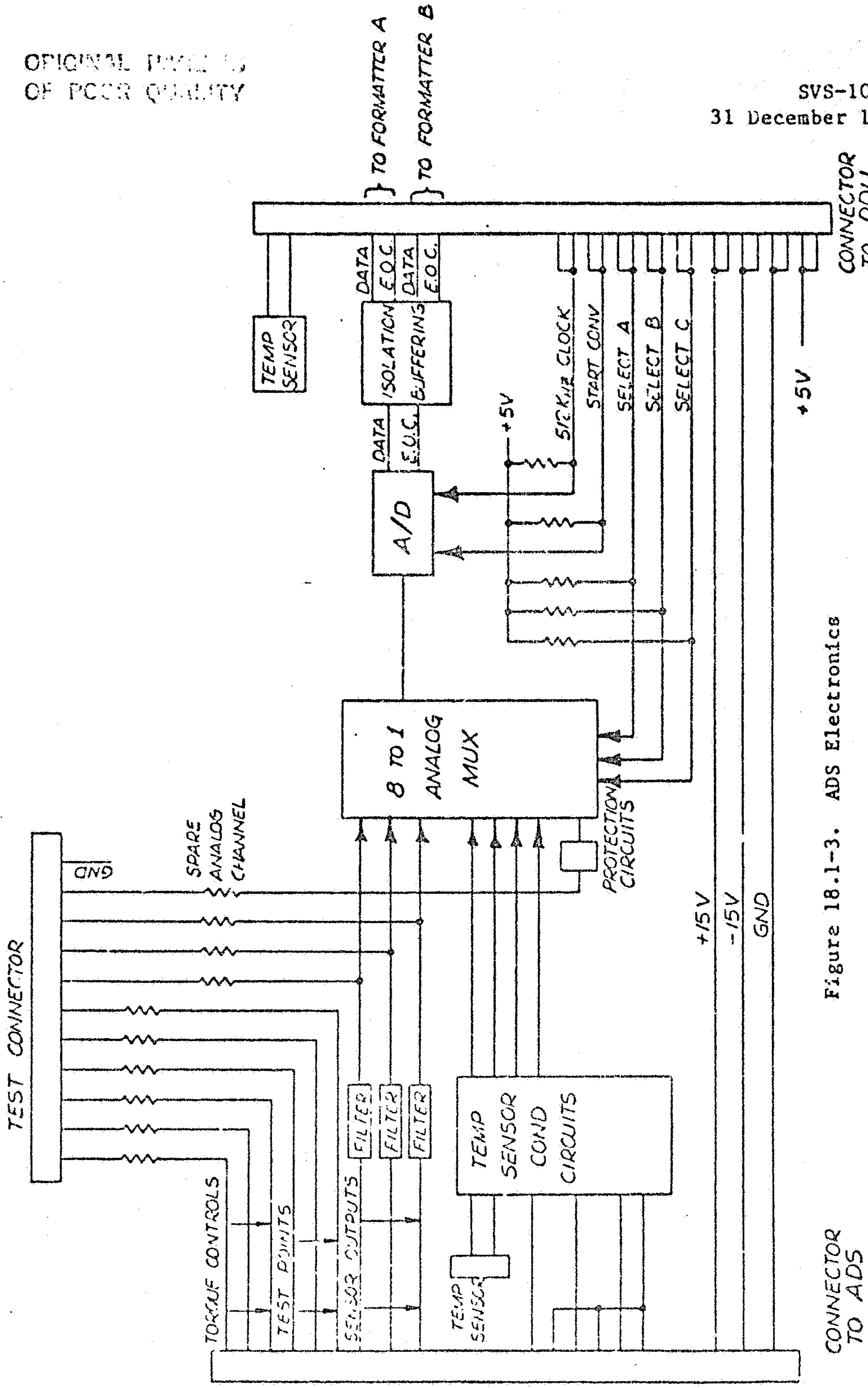

Figure 18.1-3. ADS Electronics

LSD-WPC-263

18.1.3 PCD FORMATTER

The PCD Formatter is located in the PDU and receives the following signals:

1. Angle Displacement Sensor (From ADS)
2. ADS Temperature (From ADS)
3. Gyro Data (From OBC)
4. Gyro Drift Data (From OBC)
5. Attitude Estimate (From OBC)
6. Ephemeris (From OBC)
7. TM Housekeeping Data (From OBC)
8. MSS Housekeeping Data (From OBC)
9. S/C Time Code (From DPU)
10. Formatter Status (Generated in the Formatter)
11. Sync (Generated in the Formatter)
12. MFID (Generated in the Formatter)
13. A/D Ground Reference (from ADS)
14. Telemetry Frame correlation (Generated in Formatter)

ADS data is received from the ADS electronics A/D converter circuits in serial form placed in holding registers, and packed into the serial output stream at the appropriate times. The ADS electronics sampling and channel selection are controlled by timing circuits in the PCD Formatter.

Time code data is sent to the Formatter from the DPU by means of a serial data line and a gated clock. This data stream is loaded into a 1024 x 1 bit static RAM operated in a first in/first out fashion. It is read from the RAM and placed in the telemetry stream in PCD major frame 1.

Attitude, ephemeris and gyro drift data, and selected telemetry data are received from the RIU in a single serial stream by the PDU digital electronics and are then transferred to the PCD Formatter. The various types of data comprcmising the serial input are not differentiated in the PCD Formatter. The data is loaded into and read from a second 1024 X 1 bit RAM in a similar manner to time code except for the placement of the data in the PCD telemetry frames. Gyro data is also received by circuits within the PDU digital electronics and then sent to the PCD Formatter and are likewise stored in a 1024 X 1 bit RAM, and read out as required. Data from the PDU digital electronics is sent over the common clock and data lines; separate enabling signals are provided to steer the data to the appropriate PCD Formatter circuits. Major frame synchronization and 1.024 MHz clock signals are also sent to the PCD Formatter from the RIU by the PDU. PCD Formatter status words, sync pattern, minor frame ID and major frame correlation ar internally generated and placed in the serial output stream by separate shift registers which are loaded and clocked as required by the given data format. PCD Formatter status will include a framing error flag, which when set indicates that major frame sync did not occur or that its occurance was not at the expected time; and a time code update flag to indicate that no new time code data was received during the current telemetry major frame.

Output signals from the PCD Formatter are sent to the DPU and the C&DH subsystem. The DPU is provided with serial data and clock signals. The C&DH subsystem is also sent serial data and clock signals, plus a two-times clock (64 KHz). PCD Formatter interfaces are shown in Figure 18.1-4. The format of these data is defined in the SVS-10123, Data Format Control Book, Volume II (Telemetry).

18.2 PERFORMANCE CAPABILITIES

18.2.1 ANGULAR DISPLACEMENT SENSOR PERFORMANCE

1. Sensitivity: Roll: 25 volts/milliradian
   Pitch and Yaw: 50 Volts/Milliradian
2. Threshold: <0.1 Microradians
3. Linear Range: −5 Volts to +5 Volts
   Roll: ±400 microradians
   Pitch and Yaw: ±200 microradians
4. Bandpass: 0.5 Hz to 120 Hz
5. Accuracy: Gain: ±1.2 Microradians
   Phase: ±0.6 Degrees
6. RMS Noise: <0.1 Microradians
7. Cross Axis Coupling: <0.2% of Input

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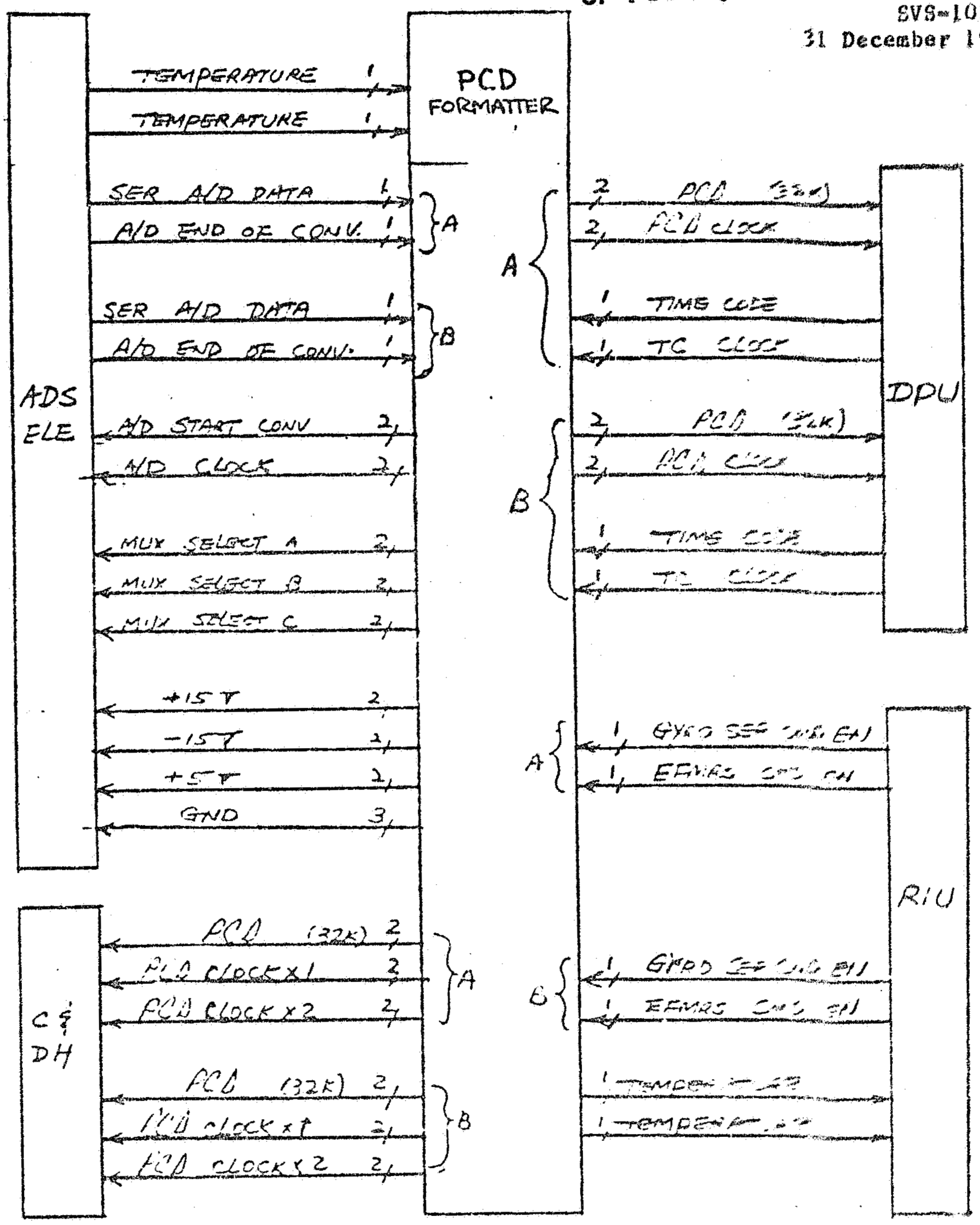

Figure 18.1-4. PDU Formatter Interfaces

18.2.2 ANALOG MULTIPLEXER AND A/D CONVERTER PERFORMANCE

1. Conversion time: 125 microseconds
2. Resolution: at least 0.1% (10 binary bits)
3. Accuracy: shall be able to be known to at least 0.1% (absolute accuracy) after ground computations
4. Range: -5.000 volts to +5.000 volts

18.2.3 PCD FORMATTER PERFORMANCE

TBS

18.3 PCD Modes of Operation

The PCD subsystem has two modes

Formatter/ADS Power ON
Formatter/ADS Power OFF

which are controlled via discrete command from RIU #6. Power switching is accomplished in the PDU. The PCD Formatter (A and B) that is powered is the same as that selected for PDU Electronics (A or B). The ADS Electronics are powered with power to either formatter.

18.4 CONSTRAINTS

TBS

18.5 REDUNDANCY

The ADS and ADS Electronics are single units without redundant backup. The PCD Formatter is block redundant with the active Formatter determined by which side of the PDU is selected.

The Formatter, DPU and PDU Power supply (as well as the other sections of the PDU) form a single functional block of redundant components which are tied together in a simple A-A configuration. See Figure 18.1-1.

18.6 COMMANDS

RIU 6 will provide the command functions to the PCD identified in the Command Directory.

18.7 TELEMETRY

Telemetry from the PCD will be defined in the Telemetry directory. Information regarding calibration curves for any PCD telemetered functions will be found in Appendix A.18.

19.0 THERMAL CONTROL SUBSYSTEM

THERMAL CONTROL SUBSYSTEM

The Thermal Control Subsystem (TCS) on the Landsat-D Flight Segment is used to generate and distribute the heat energy required to maintain the spacecraft and its components within the designed temperature limits. The TCS is made up of both active and passive elements: heaters, which transform electrical energy into heat energy; blankets, which reduce the rate of heat loss; and louvers, which promote the dissipation of heat. The heaters are controlled by mechanical thermostats or by circuits using themistors as sensing elements. These control devices measure the local temperature and cycle the heaters on and off within predetermined limits. Thermistors are also employed to measure the temperature at various points throughout the Flight Segment to provide data for inclusion in the telemetry stream. The heater circuits are enabled and disabled by command from the OBC, and in some cases the thermostats can be bypassed to permit heaters to be turned on and off by ground command.

A separate set of heaters is hard-wired to the STS/MMS interface connector. They maintain the Landsat-D Flight Segment temperature after it has been retrieved by the Space Shuttle.

19.1 FUNCTIONAL DESCRIPTION

As far as the TCS is concerned, the Landsat-D Flight Segment can be thought of as being divided into four parts:

1. IM Structure
2. IM Subsystems
3. MMS Structure
4. MMS Subsystems

19.1.1 THERMAL ELEMENTS, ON-ORBIT OPERATIONS

19.1.1.1 IM Structure

19.1.1.1.1 Heaters and Heater Controls

There are approximately fifty heaters located throughout the IM Structure which are used during on-orbit operations.

They consist of either one strip (single), two strips (co-lam), or three strips (tri-lam). The heaters are grouped, and each group is turned on and off either by control circuits (using thermistors as sensing elements) located in the Power Distribution Unit, or by thermostat To locate the heaters, thermostats, and thermistors, see GE Drawing No. 47J255181, Thermal Subsystem Installation. The table on sheet 1 of this drawing, entitled "On-Orbit Environment Thermal

Control", lists the heaters, thermostats, and thermistors. The table also shows the construction and power rating of the heaters.

19.1.1.1.2 Temperature Sensors (Telemetry)

There are approximately 41 thermistors distributed throughout the IM Structure which monitor the structure temperature. The output of these sensors is inserted into the telemetry stream. These thermistors are listed in the Telemetry Temperature Sensor Location Guide, GE Drawing No. 47J255181, Thermal Subsystem Installation, sheet 1. The guide gives the key to the location of each sensor as well as its telemetry mnemonic.

19.1.1.2 IM Subsystems

The location of heaters, thermistors, and thermostats is shown on the following figures for the IM subsystem listed. Locations for other IM subsystems are TBS.

Figure 19.1-1. WBCS (Wideband Module)
Figure 19.1-2. WBCS (RF Compartment)
Figure 19.1-3. GPS (R/PA)
Figure 19.1-4. DASB

19.1.1.3 MMS Structure

There are six heaters, six thermostats, and six heaters attached to the MMS structure as shown in Figure 19.1-5. Two heaters and two thermostats are attached to the longerons at each of the three structural junctures near the IM. A thermistor is located within each of these junctures, and within each of the three structural junctures toward the aft end of the MMS.

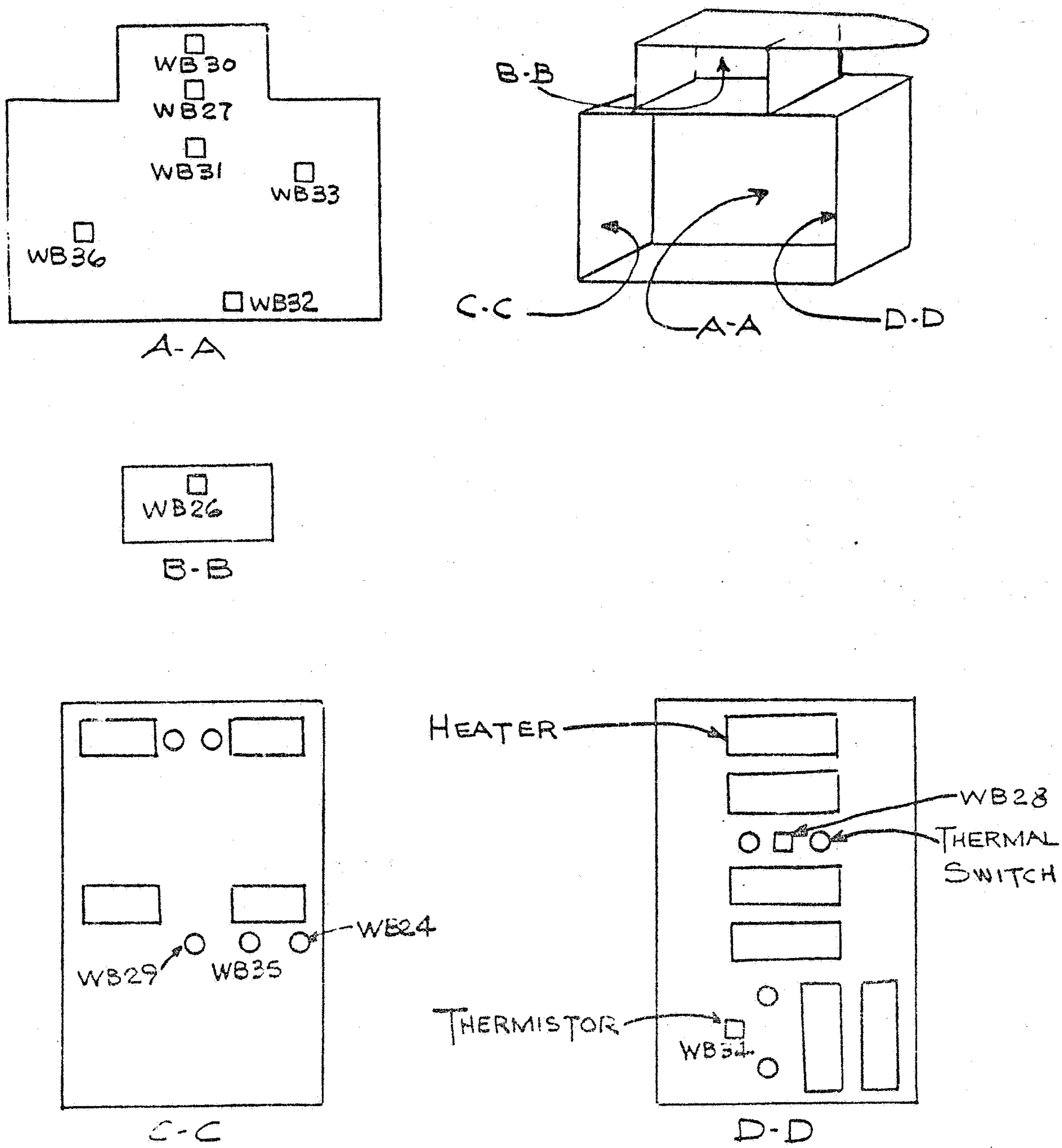

Figure 19.1-1. Location of Heating Elements, WBCS Wideband Module

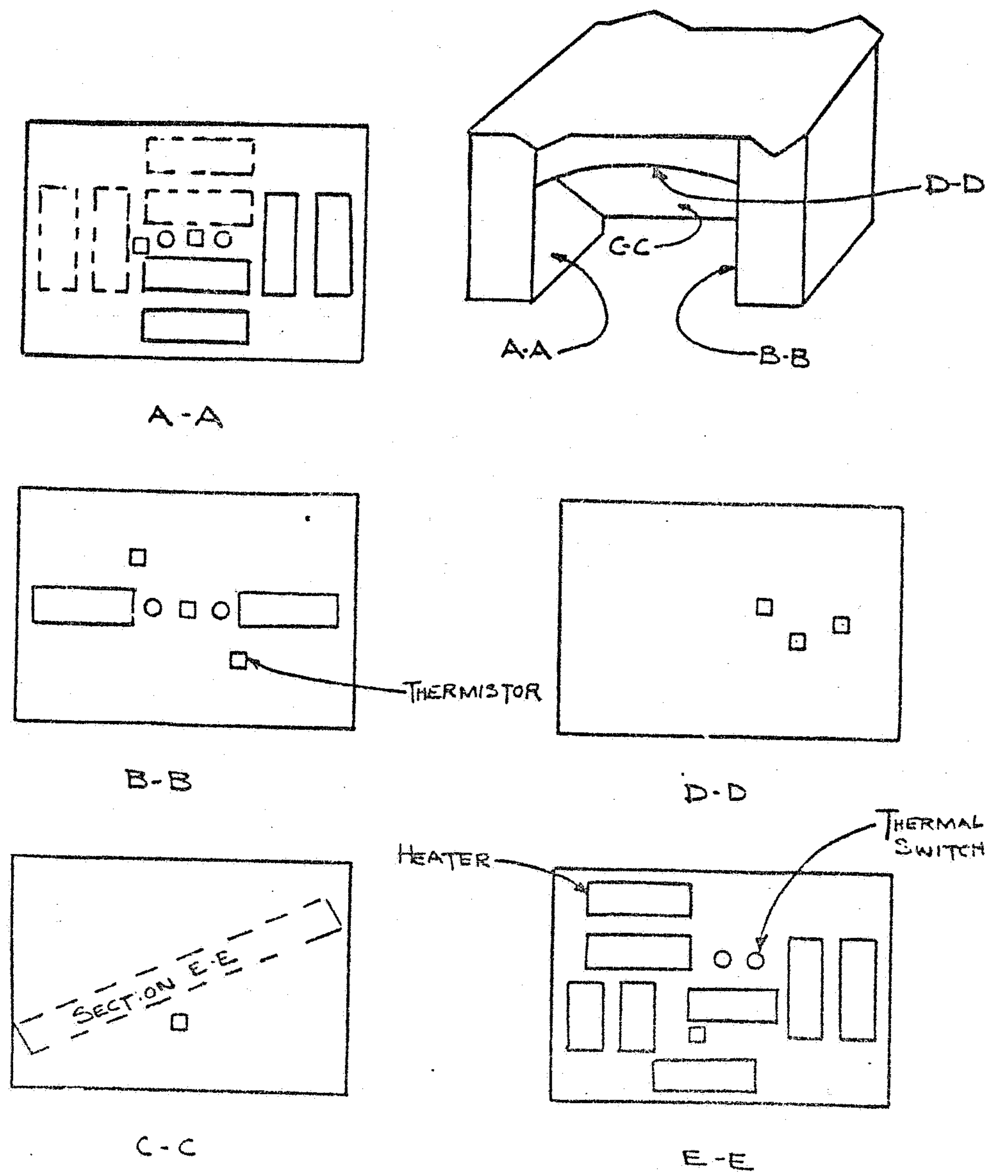

Figure 19.1-2. Location of Heating Elements, WBCS RF Compartment

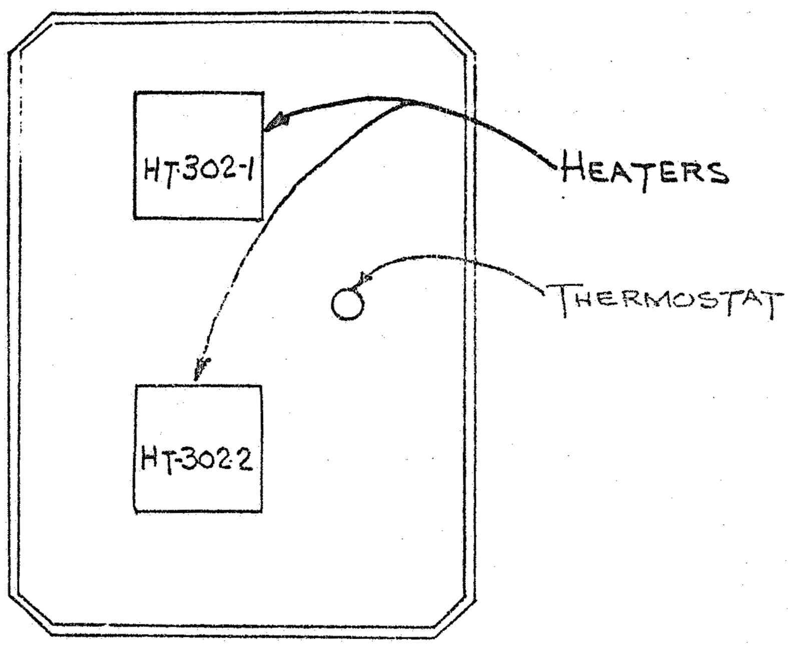

Figure 19.1-3. Location of Heating Elements, GPS (R/PA)

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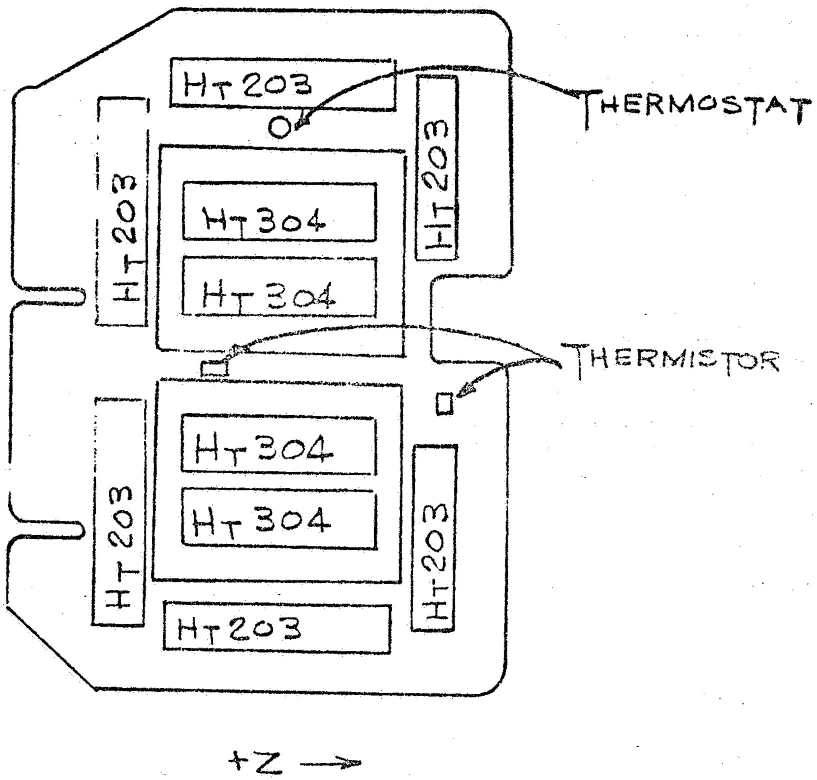


Figure 19.1-4. Location of Heating Elements - DASB

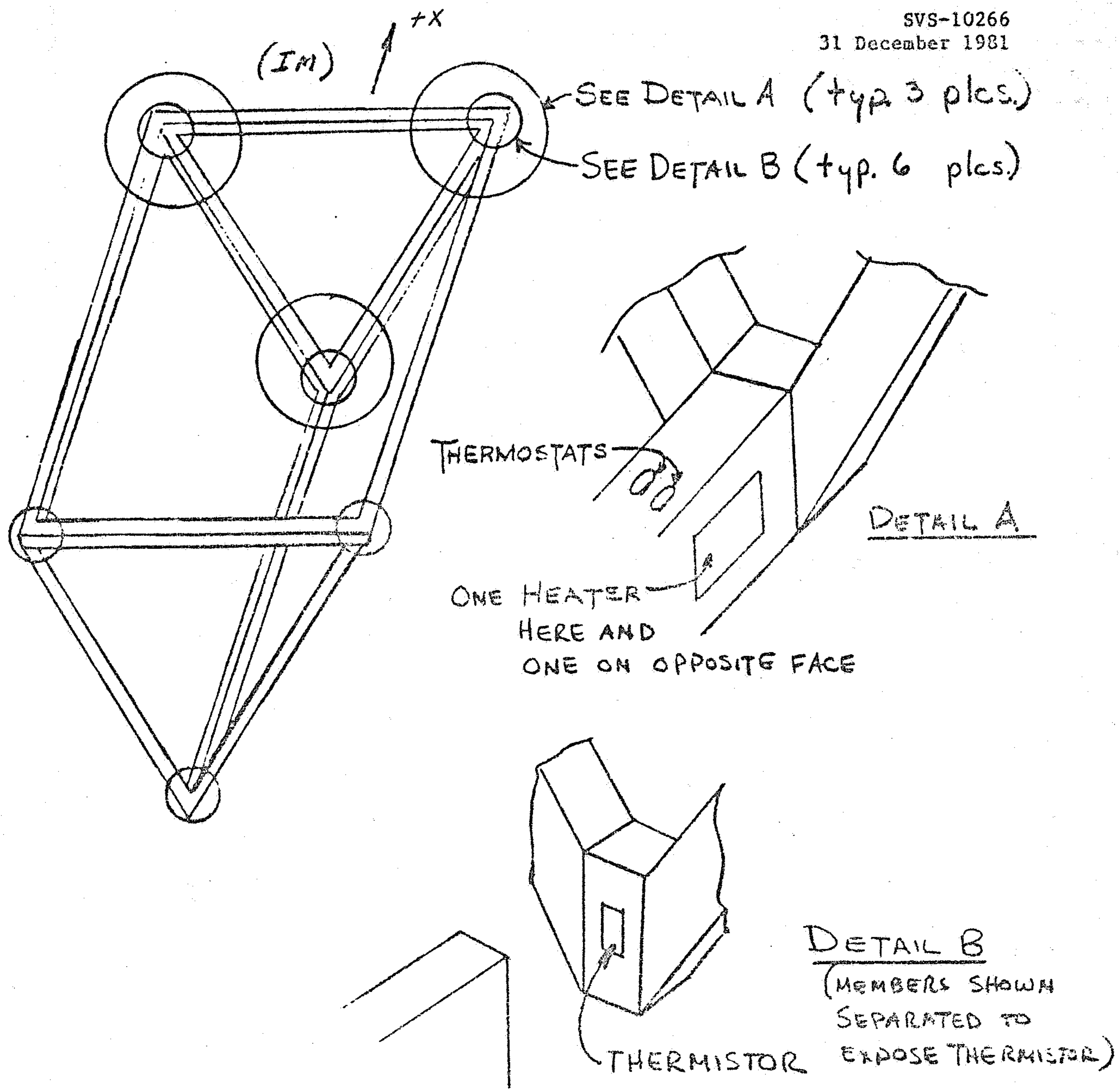


Figure 19.1-5. Location of Heating Elements - MMS Structure

19.1.1.4 MMS Subsystems

The location of heaters, thermostats, and thermistors is shown on the following figures for the MMS Subsystems listed. Locations for other MMS subsystems are TBS.

Figure 19.1-6. ESAM

19.1.2 THERMAL ELEMENTS, RECOVERY ENVIRONMENT

19.1.2.1 IM Structure

There are approximately 34 heaters which are used to maintain the temperature of the IM Structure during the recovery phase. These are all single-element heaters, and are hardwired to the STS/MMS interface connector. The heaters are grouped and each group is controlled by a thermostat.

The heaters, their power ratings, and location are listed in the table, "Shuttle Environment Thermal Control", GE Drawing No. 47J255181, Thermal Subsystem Installation, sheet 1. The thermostat locations are also shown on this table.

19.1.2.2 IM Subsystems

TBS

19.1.2.3 MMS Structure

TBS

19.1.2.4 MMS Subsystems

TBS

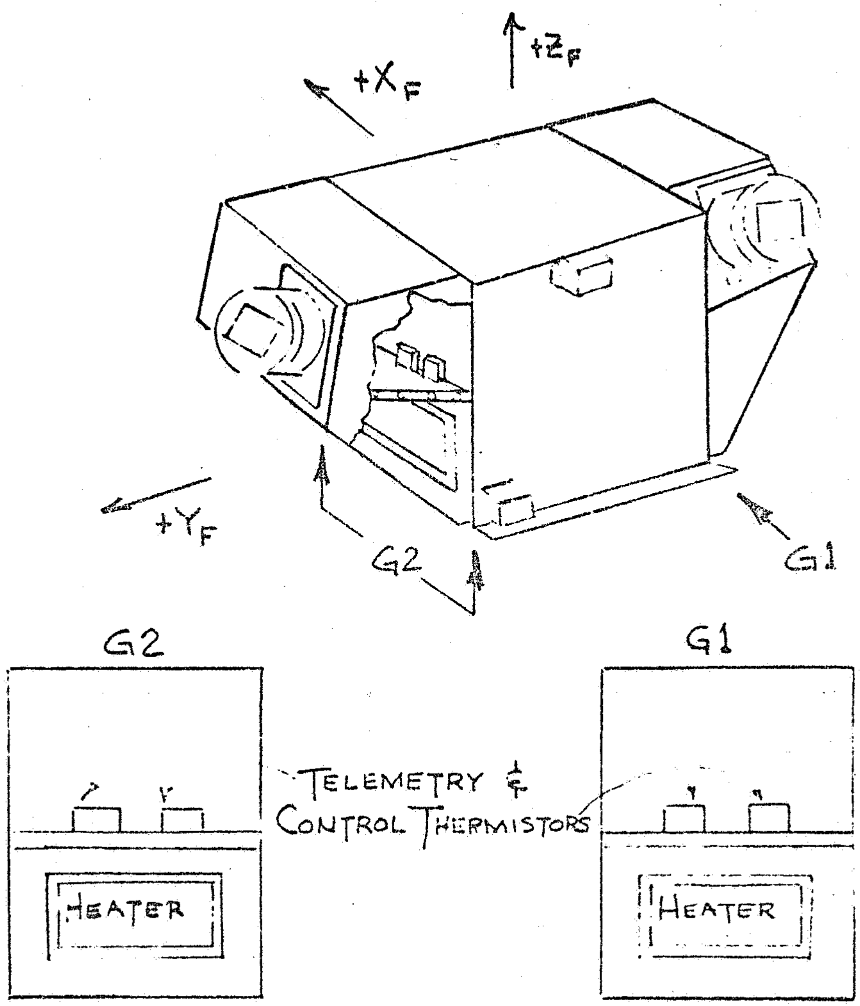
19.1.3 PASSIVE THERMAL CONTROL ELEMENTS

19.1.3.1 Thermal Control Louvers

Both the MMS and IM of the Landsat-D employ thermal control louvers to regulate the temperature level of critical components. For the MMS, the following subsystems utilize louvers:

1. MACS (GE S/S)
2. C&DH (Fairchild S/S)
3. MPS (Fairchild S/S)

On the IM, only the TM employs thermal control louvers. A discussion of this unit is given in Section 14.



NOTE: NO MECHANICAL THERMOSTATS IN ESAM

Figure 19.1-6. Location of Heating Elements, ESAM

19.1.3.2 Insulation Blankets

GE Drawing No. 47A255161 defines the configuration and materials employed in insulation blankets that will be installed at various locations throughout the Landsat-D Instrumentation Module. Currently, the location and installation details for the blankets is being designed. These details will be incorporated as a Drawing Change to GE Drawing 47J255181.

A description of the test, contamination control and blanket cleaning procedures can be found in GE Specification 171A4882.

19.2 PERFORMANCE CAPABILITIES

19.2.1 ALLOWABLE TEMPERATURES AND SET POINTS

The thermal control system of Landsat-D has two independent sets of heaters. One set is employed when the vehicle is launched on the Delta booster, the other set is employed when the vehicle is recovered by the Space Shuttle. Table 19.2-1 defines the heater parameters for each subsystem, and the corresponding set points of the thermostats. Similarily, Table 19.2-2 provides this information for the Space Shuttle recovery.

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Table 19.2-1. - HEATER/THERMOSTAT DEFINITION - LAUNCH, ON-ORBIT OPERATION

HEATER CIRCUIT LOCATION/COMPONENT	THERMOSTAT	CURRENT LIMIT AT 33V (AMPS)	CURRENT DRAIN (AMPS)		REQUIRED EFFECTIVE HEATER SIZE			IDENTICAL REDUNDANT HEATERS	THERMOSTAT TEMPERATURE °C				OPERATIONAL USE
			25V	33V	OHMS	WATTS 25V	WATTS 33V		SET PT.	MIN CLOSE	MAX OPEN	MIN OPEN	
USS #1 -Y EQUIP. PANEL/CIRCUIT A	SOLID STATE	1.32	0.76	1.0	32.9	19	33.1	YES	13	12	19	15	LAUNCH/ON ORBIT/ SAFE HOLD
USS #2 -Y EQUIP. PANEL/CIRCUIT B	SOLID STATE	1.32	1.00	1.32	25.0	25	43.5	YES	13	12	19	15	LAUNCH/ON ORBIT/ SAFE HOLD
USS #1 +Y EQUIP. PANEL	* BI-METALLIC (THREE)	/	2.6	3.44	9.6	70	113.4	YES	13.8	12.2	18.3	13.3	LAUNCH/ON ORBIT/ SAFE HOLD
S-BAND XMITTER PANEL	SOLID STATE	1.32	1.0	1.32	25.0	25	43.5	YES	8	7	14	10	LAUNCH/ON ORBIT SAFE HOLD
HMA/TM ATTACH FITTINGS	SOLID STATE	1.32	1.0	1.32	25.0	25	43.5	NO	13	12	19	15	LAUNCH/ON ORBIT/ SAFE HOLD
MSS MOUNT/CIRCUIT A	SOLID STATE	1.32	1.0	1.32	25.0	25	43.5	YES	13	12	19	15	LAUNCH/ON ORBIT/ SAFE HOLD
MSS MOUNT/CIRCUIT B	** BI-METALLIC (ONE)	2.00	1.4	1.84	17.9	35	60.0	NONE	13.8	12.2	18.3	13.3	SAFE HOLD
WS MODULE IF/CLOSING PANEL	SOLID STATE	1.32	1.76	1.0	32.9	19	33.1	YES	13	12	19	15	LAUNCH/ON ORBIT/ SAFE HOLD

* R4379 - CLOSING AND OPENING SET POINTS HAVE TOLERANCE OF ± 2.78°C WITH A DIFFERENTIAL OF 5°C
** R4375 - CLOSING SET POINT + 1.67°C; OPEN POINT - CLOSE POINT + 1.11°C TO 2.78°C
@ BOTH CIRCUITS REQUIRED FOR INERTIAL SAFE HOLD
/ CURRENT LIMIT TO BE INVESTIGATED FOR COMPATIBILITY WITH HEATER REQUIREMENTS

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Table 19.2-2. Heater/Thermostat Definition - Shuttle Operation

HEATER CIRCUIT LOCATION/COMPONENT	Thermostat	Required Heater Power (watts)	Required Effective Heater Size			Current Drain (amps)		Identical Redundant Heaters	Thermostat Temperature °C			
			Ohms	Watts 24V	Watts 28V	24V	28V		Set Pt.	Min Close	Max Open	Min Open
-Y EQUIPMENT PANEL	Bi-Metallic	33.0	17.6	33	44.6	1.36	1.59	None	3.8	2.2	6.6	3.3
+Y EQUIPMENT PANEL	*Bi-Metallic	44.0	13.1	44	59.9	1.83	2.14	None	5.0	2.2	12.7	7.2
S-BAND TRANSMITTER PANEL	Bi-Metallic	24.2	24.0	24	32.7	1.00	1.17	None	3.8	2.2	6.6	3.3
MISSION ADAPTER	*Bi-Metallic	80.0	6.5	89	121.0	3.69	4.31	None	5.0	2.2	12.7	7.2
MSS MOUNT	Bi-Metallic	30.5	18.6	31	42.2	1.29	1.51	None	3.8	2.2	6.6	3.3
WB MODULE I/F	Bi-Metallic	18.7	30.3	19	25.9	0.79	0.92	None	3.8	2.2	6.6	3.3
CLOSING PANEL - PEDESTAL ATTACHMENT	Bi-Metallic	6.2	96.0	6	8.2	0.25	0.29	None	3.8	2.2	6.6	3.3

*R4379 - All other thermostats are R4375.

Temperature limits and the set points for the MMS Structure and all of the Landsat-D components with heaters are TBS. Heater and thermostat requirements for the IM are discussed in GE PIR-IK54-LS/D 790.

19.3 MODES OF OPERATION

TBS

19.4 CONSTRAINTS

TBS

19.5 REDUNDANCY/CROSS STRAPPING

TBS

19.6 COMMANDS

Table 19.2-3 lists the commands used in the Thermal Control Subsystems.

19.7 TELEMETRY

Table 19.2-4 lists the telemetry points for the Landsat-D spacecraft. The points are listed by subsystem and are identified by their telemetry mnemonics. Operating limits and conversion curve coefficients are also shown.

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Table 19.2-3. Commands, Thermal Control Subsystem

Mnemonic	RIU/Channel/Serial Magnitude (XX/XX/XXXXXXXXXXXXXXXX)	Description
HTR1EN	0150	ENA HTR 1
HTR1DI	0152	DIS HTR 1
HTR2EN	0155	HTR 2 ENA
HTR2DI	0157	HTR 2 DIS
HTG1ON	0233	MACS HTR GRP 1 ON
HTG1OFF	0235	MACS HTR GRP 1 OFF
HTG2ON	0237	MACS HTR GRP 2 ON
HTG2OFF	0239	MACS HTR GRP 2 OFF
ST2HTRON	0241	FHST 2 HTR ON
ST1HTRON	0242	FHST 1 HTR ON
ST12HTOF	0243	FHST 1/2 HTRS OFF
HTG3ON	0248	MACS HTR GRP 3 ON
HTG3OFF	0250	MACS HTR GRP 3 OFF
HTRARM	0309	HTR ARM
HTRDIS	0310	HTR DISARM
TH2BYR	0322	HTR THRM 2 BYPS ENA/DIS RESET
TH2BYS	0323	HTR THRM 2 BYPS ENA/DIS SET
TH1BYR	0324	HTR THRM 1 BYPS EN/DIS RESET
TH1BYS	0325	HTR THRM 1 BYPS EN/DIS SET
HTRRST	0326	AUTO HTRS ON/OFF EN/DIS RESET
HTRSET	0327	AUTO HTRS ON/OFF EN/DIS SET
B3TSRS	0328	BAT 3 THRM SW ENA/DIS RESET
B3TSST	0329	BAT 3 THRM SW EN/DIS SET
B2TSRS	0330	BAT 2 THRM SW ENA/DIS RESET
B2TSST	0331	BAT 2 THRM SW ENA/DIS SET
B1TSRS	0332	BAT 1 THRM SW ENA/DIS RESET
B1TSST	0333	BAT 1 THRM SW ENA/DIS SET
ENAHTA	0404	SCCU HTR A ENA
DISHTA	0414	SCCU HTR A DIS
BYPTHA	0421	SCCU HTR A THERMO BYPS
ENATHA	0431	SCCU HTR A THERMO ENA
ENAHTB	0433	SCCU HTR B ENA
DISHTB	0443	SCCU HTR B DIS
BYPTHB	0448	SCCU HTR B THERMO BYPS
ENATHB	0458	SCCU HTR B THERMO EN
S1HAEN	04700001000101110011	UPR SUPP STR HTR 1A ENA
S1HADI	04700010000110110011	UPR SUPP STR HTR 1A DIS
S1HBEN	04700011000100110011	UPR SUPP STR HTR 1B ENA
S1HBDI	04700100000111010011	UPR SUPP STR HTR 1B DIS
S1THBY	04700101000101010011	UPR SUPP STR HTR 1 THRM BYP
S1THEN	04700110000110010011	UPR SUPP STR HTR 1 THRM EN
SBHAEN	04700111000100010011	DASB RAD PRI HTR EN
SBHADI	04701000000111100011	DASB RAD PRI HTR DIS
SBHBEN	04701001000101100011	DASB RAD RED HTR EN
SBHBDI	04701010000110100011	DASB RAD RED HTR DIS
SBTHBY	04701011000100100011	DASB RAD HTR THERMO BYPS
SBTHEN	04701100000111000011	DASB RAD HTR THERMO EN

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Table 19.2-3. Commands, Thermal Control Subsystem (Cont'd)

Mnemonic	RIU/Channel/Serial Magnitude (XX/XX/XXXXXXXXXXXXXXXX)	Description
MAHAEN	04700001001001110100	TM/MISS ADAPT PRI HTR EN
MAHADI	04700010001010110100	TM/MISS ADAPT PRI HTR DIS
MAHBEN	04700011001000110100	TM/MISS ADAPT RED HTR EN
MAHBDI	04700100001011010100	TM/MISS ADAPT RED HTR DIS
MATHBY	04700101001001010100	TM/MISS ADAPT HTR THERMO BYPS
MATHEN	04700110001010010100	TM/MISS ADAPT HTR THERMO ENA
MSHAEN	04700111001000010100	MSS INTER PRI HTR EN
MSHADI	04701000001011100100	MSS INTER PRI HTR DIS
MSHBEN	04701001001001100100	MSS INTER RED HTR EN
MSHBDI	04701010001010100100	MSS INTER RED HTR DIS
MSTHBY	04701011001000100100	MSS INTER HTR THERMO BYPS
MSTHEN	04701100001011000100	MSS INTER HTR THERMO EN
WBHAEN	04700001001101110101	WB MOD INTER PRI HTR ENA
WBHADI	04700010001110110101	WB MOD INTER PRI HTR DIS
WBHBEN	04700011001100110101	WB MOD INTER RED HTR EN
WBHBDI	04700100001111010101	WB MOD INTER RED HTR DIS
WBTHBY	04700101001101010101	WB MOD INTER HTR THRMO BYPS
WBTHEN	04700110001110010101	WB MOD INTER HTR THERMO EN
S2HAEN	04700111001100010101	UPR SUPP STR HTR 2A PRI EN
S2HADI	04701000001111100101	UPR SUPP STR HTR 2A PRI DIS
S2HBEN	04701001001101100101	UPR SUPP STR HTR 2B RED EN
S2HBDI	04701010001110100101	UPR SUPP STR HTR 2B RED DIS
S2THBY	04701011001100100101	UPR SUPP STR HTR 2 THRM BYPS
S2THEN	04701100001111000101	UPR SUPP STR HTR 2 THRMO EN
TMHAEN	04700001010001110110	TM SFEHLD HTR 1 EN
TMHADI	04700010010010110110	TM SFEHLD HTR 1 DIS
TMHBEN	04700011010000110110	TM SFEHLD HTR 2 EN
TMHBDI	04700100010011010110	TM SFEHLD HTR 2 DIS
TMTHBY	04700101010001010110	TM SFEHLD HTR THRMO BYPS
TMTHEN	04700110010010010110	TM SFEHLD HTR THRMO EN
PH8AEN	04700111010000010110	PYLD HTR 8 PRI EN
PH8ADI	04701000010011100110	PYLD HTR 8 PRI DIS
PH8BEN	04701001010001100110	PYLD HTR 8 RED EN
PH8BDI	04701010010010100110	PYLD HTR 8 RED DIS
PTH8BY	04701011010000100110	PYLD THRM 8 BYPS
PTH8EN	04701100010011000110	PYLD THRM 8 ENA
SCH1EN	04700001010101110111	S/C HTR 1 EN
SCH1DI	04700010010110110111	S/C HTR 1 DIS
SCTH1BY	04700011010100110111	S/C THRM 1 BYPS
SCTH1EN	04700100010111010111	S/C THRM 1 EN
SCH2EN	04700101010101010111	S/C HTR 2 ENA
SCH2DI	04700110010110010111	S/C HTR 2 DIS
SCTH2BY	04700111010100010111	S/C THRM 2 BYPS
SCTH2EN	04701000010111100111	S/C THRM 2 ENA
SCH3EN	04701001010101100111	S/C HTR 3 ENA
SCH3DI	04701010010110100111	S/C HTR 3 DIS
SCTH3BY	04701011010100100111	S/C THRM 3 BYPS
SCTH3EN	04701100010111000111	S/C THRM 3 ENA
SCH4EN	04700001011001111000	S/C HTR 4 ENA

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Table 19.2-3. Commands, Thermal Control Subsystem (Cont'd)

Mnemonic	RIU/Channel/Serial Magnitude (XX/XX/XXXXXXXXXXXXXXXX)	Description
SCH4DI	04700010011010111000	S/C HTR 4 DIS
SCTH4BY	04700011011000111000	S/C THRM 4 BYPS
SCTH4EN	04700100011011011000	S/C THRM 4 ENA
SCH5EN	04700101011001011000	S/C HTR 5 ENA
SCH5DI	04700110011010011000	S/C HTR 5 DIS
SCTH5BY	04700111011000011000	S/C THRM 5 BYPS
SCTH5EN	04701000011011101000	S/C THRM 5 ENA
SCH6EN	04701001011001101000	S/C HTR 6 ENA
SCH6DI	04701010011010101000	S/C HTR 6 DIS
SCTH6BY	04701011011000101000	S/C THRM 6 BYPS
SCTH6EN	04701100011011001000	S/C THRM 6 ENA
ES2HTEN	0419	ESA 2 HTR ENABLE
ES1HTDIS	0425	ESA 1 HTR DIS/LOGIC DIS
ES1HTEN	0440	ESA 1 HTR ENABLE
ES2HTDIS	0454	ESA 2 HTR DIS/LOGIC DIS
PTKHTEN	04700001110001111110	PM-1A PRIM TANK HTR ENA
PTKHTDIS	04700010110010111110	PM-1A PRIM TANK HTR DIS
RTKHTEN	04700111110000011110	PM-1A RED TANK HTR ENA
RTKHTDIS	04701000110011101110	PM-1A RED TANK HTR DIS
PLHTEN	04700011110000111110	PM-1A PRIM LINE HTR ENA
PLHTDIS	04700100110011011110	PM-1A PRIM LINE HTR DIS
LHTTHBY	04700101110001011110	PM-1A LNE HTR THRMST BYPS
LPTTHEN	04700110110010011110	PM-1A LNE HTR THRMST ENA
RLNHTEN	04701001110001101110	PM-1A RED LINE HTR ENA
RLNHTDIS	04701010110010101110	PM-1A RED LINE HTR DIS
TKHTTHBY	04701011110000101110	PM-1A TANK HTR THRM BYPS
PHTRAUON	0501	PRI HTRS ON AUTO/MAN OFF
RHTRONAM	0502	RED HTRS ON AUTO/MAN OFF
PAHTONMM	0503	REM A PRI HTR ON MAN MDE
PBHTONMM	0504	REM B PRI HTR ON MAN MDE
PCHTONMM	0505	REM C PRI HTR ON MAN MDE
PDHTONMM	0506	REM D PRI HTR ON MAN MDE
PSHTONMM	0507	SHLF PRI HTRS ON MAN MDE
RAHTONMM	0508	REM A RED HTR ON MAN MDE
RBHTONMM	0509	REM B RED HTR ON MAN MDE
RCHTONMM	0510	REM C RED HTR ON MAN MDE
RDHTONMM	0511	REM D RED HTR ON MAN MDE
RSHTONMM	0512	SHLF RED HTRS ON MAN MDE
PHTREN	0513	ENA PRIM HTR BUS
RHTREN	0514	ENA RED HTR BUS
PHTRDIS	0561	DIS PRIM HTR BUS
RHTRDIS	0562	DIS RED HTR BUS
ENSMAHTR	0601	TM SMA HTR ENABLE
EXSBYHTR	0610	TM EXT STBY HTR ENA
EMSSHTRB	0612	MSS INTFC HTR B ENA
HHTRON	0622	HINGE HTRS ON
ENU3AHTR	0623	ENA UP SUPP STR 3A HTR
ENU3BHTR	0625	ENA UP SUPP STR 3B HTR
XAU3CHTR	0628	SLT BUS A FOR STR 3C HTR
ENU3CHTR	0630	ENA UP SUPP STR 3C HTR

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Table 19.2-3. Commands, Thermal Control Subsystem (Cont'd)

Mnemonic	RIU/Channel/Serial Magnitude (XX/XX/XXXXXXXXXXXXXXXX)	Description
DSSMAHTR	0636	TM SHA HTR DISABLE
DXSBYHTR	0639	TM EXT STBY HTR DIS
DSU3CHTR	0640	DIS UP SUPP STR 3C HTR
DMSSHTRB	0641	MSS INTERFC HTR B DISABLE
DS3ABHTR	0650	DIS UP SUPP STR 3A/3B HTR
XBU3CHTR	0657	SLT BUS B FOR STR 3C HTR
THSDNDIS	0702	THRM SHTDWN DIS
CFPAONT1	0710	CFPA HTR CTL ON/T1 SLT/TLM ON
BBHTRENA	0716	BLKBDY HTR CTL ON/T1 SLT
THSDNENA	0736	THRM SHTDWN ENA
CFPAOFF	0744	CFPA HTR CTL OFF
BBHTRDIS	0746	BLKBDY HTR CTL OFF/BKUP OFF
PSMAENA	08711000000000000000	SCAN MIR ASSY +Z HTR CTLR ON
PSMADIS	08710100000000000000	SCAN MIR ASSY +Z HTR CTLR OFF
NSMAENA	08710010000000000000	SCAN MIR ASSY -Z HTR CTLR ON
NSMADIS	08710001000000000000	SCN MR ASY -Z HTR CTLR OFF
ISOUTENA	08710000100000000000	COOLR INT STG OGAS HTR EN
ENAISTC	08710000010000000000	COOLR INT STG HTR CTLR ON
DISISTC	08710000001000000000	COOLR INT STG HTR CTLR OFF/HTR
BFHTRENA	08720010000000000000	BFL HTR CTRLR ON
BFHTRBU	08720001000000000000	BFL HTR BKUP ON
BFHTRDIS	08720000100000000000	BFL HTR CTRLR OFF/BKUP OFF
CSOUTENA	08720000010000000000	C STG OGAS HTR ENA
ENACSHTR	08720000001000000000	C STG HTR CTRLR ON/TLM ON
DISCSHTR	08720000000100000000	C STG HTR CTRLR OFF/OGAS HTR DIS
PRGHEN	09710000000000100100	PRI REC/GDA HTRS ENA
PRGHDIS	09710000000010101100	PRI REC/GDA HTRS DIS
PXHTREN	09710000000000010010	PRI X-B TWTA HTRS ENA
PXHTRDIS	09710000000010011010	PRI X-B TWTA HTRS DIS
PWBHEN	09710000000001010110	PRI WB MOD HTRS ENA
PWBHDIS	09710000000011011110	PRI WB MD HTRS DIS
RRGHEN	09710000000001010001	RED REC/GDA HTRS ENA
RRGHDIS	09710000000011011001	RED REC/GDA HTRS DIS
RXHTREN	09710000000001000101	RED X-B TWTA HTRS ENA
RXHTRDIS	09710000000011001101	RED X-B HTR DIS
RWBHTEN	09710000000000100011	RED WB MOD HTRS ENA
RWBHDIS	09710000000010101011	RED WB MD HTRS DIS
PRGHEN	09720000000000100100	PRI REC/GDA HTRS ENA
PRGHDIS	09720000000010101100	PRI REC/GDA HTRS DIS
PXHTREN	09720000000000010010	PRI X-B TWTA HTRS ENA
PXHTRDIS	09720000000010011010	PRI X-B TWTA HTRS DIS
PWBHEN	09720000000001010110	PRI WB MOD HTRS ENA
PWBHDIS	09720000000011011110	PRI WB MD HTRS DIS
RRGHEN	09720000000001010001	
RRGHDIS	09720000000011011001	RED REC/GDA HTRS DIS
RXHTREN	09720000000001000101	RED X-B TWTA HTRS ENA
RXHTRDIS	09720000000011001101	RED X-B HTR DIS
RWBHTEN	09720000000000100011	RED WB MD HTRS ENA
RWBHDIS	09720000000010101011	RED WB MOD HTRS DIS

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Table 19.2-4. Telemetry Points, Thermal Control Subsystem

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
MPS			
	P31TSWA	BATT 1 THML SW STAT A RSET/SET	
	PTH2BPB	HTR THMST 2 BYPASS STAT B RSET/SET	
	PTH1BPB	HTR THMST 1 BYPASS STAT B RSET/SET	
	PAUHTRB	AUTO HTR ON/OFF STAT B RSET/SET	
	P32TSWA	BATT 2 THML SW STAT A RSET/SET	
	PB30T	BATT 3 TEMP NORMAL/OVERLIMIT	
	PB20T	BATT 2 TEMP NORMAL/OVERLIMIT	
	PB10T	BATT 1 TEMP NORMAL/OVERLIMIT	
	PB3TSWA	BATT 3 THML SW STAT A RSET/SET	
	PHTARMA	HTR RELAY DRVR RIU A DISARM/ARM	
	PB3TSWB	BATT 3 THML SW STAT B RSET/SET	
	PB2TSWB	BATT 2 THML SW STAT B RSET/SET	
	PB1TSWB	BATT 1 THML SW STAT B RSET/SET	
	PTH2BPA	HTR THMST 2 BYPASS STAT A RSET/SET	
	PTH1BPA	HTR THMST 1 BYPASS STAT A RSET/SET	
	PAUHTRA	AUTO HTR ON/OFF STAT A RSET/SET	
	PHTARMB	HTR RELAY DRVR RIU B DISARM/ARM	
	PTBAT1P	BATT 1 TEMP PRI	68,79,164,180,0
	PTBAT1R	BATT 1 TEMP RED	68,79,164,180,0
	PTBAT2P	BATT 2 TEMP PRI	68,79,164,180,0
	PTBAT2R	BATT 2 TEMP RED	68,79,164,180,0
	PTPCU1	PCU TEMP 1	50,58,164,180,0
	PTBAT3P	BATT 3 TEMP PRI	68,79,164,180,0
	PTPCU2	PCU TEMP 2	50,58,164,180,0
	PTBAT3R	BATT 3 TEMP RED	68,79,164,180,0
	PTPCU3	PCU TEMP 3	50,58,164,180,0
	PTBPA	BPA TEMP	50,58,164,180,0
	PTSPRU	PRU TEMP	50,58,164,180,0
	PTSCA	SCA TEMP	50,58,164,180,0
	PTMPS1	MOD TEMP 1	50,58,164,180,0
	PTMPS2	MOD TEMP 2	50,58,164,180,0
	PTMPS3	MOD TEMP 3	50,58,164,180,0
	PTMPS4	MOD TEMP 4	50,58,164,180,0
	PB1TS	BATTERY 1 TH SW E/D STATUS	
	PB2TS	BATTERY 2 TH SW E/D STATUS	
	PB3TS	BATTERY 3 TH SW E/D STATUS	
	PAUHTR	AUTO HEATER ON/OFF STATUS	
	PTH1BP	HTR 1 THMST BYPASS STATUS	
	PTH2BP	HTR 2 THMST BYPASS STATUS	

*Red Low, Yellow Low, Yellow High, Red High, Delta

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Table 19.2-4. Telemetry Points, Thermal Control Subsystem (Cont'd)

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
WBCS			
	WRRFGDH	HEATERS REDUNDANT RFC/GDA ON/OFF	
	WRXTWTAH	HEATERS REDUNDANT X-BAND TWTA ON/OFF	
	WRWBMH	HEATERS REDUNDANT WBM (PSU & GDE) ON/	
	WRELMOTT	GDA ELEVATION MOTOR TEMP REDUNDANT	
	WPAZMOTT	GDA AZIMUTH MOTOR TEMP PRIME	
	WNRFEEDT	RFC PANEL (NEAR FEED) TEMP	
	WKUDIPT	RFC KU DIPLEXER TEMP	
	WSPARE1T	RFC SPARE TEMP 1	
	WPKTWTBT	RFC KU-TWTA BASEPLATE TEMP PRIME	
	WATFST	RFC AUTOTRACK FREQ SOURCE TEMP	
	WGDAMTT	RFC PANEL (GDA MOUNT) TEMP	
	WKUPCONT	RFC KU UPCONVERTER TEMP	
	WATFEEDT	RFC KU AUTOTRACK FEED ASSY TEMP	
	WSPARE2T	RFC SPARE TEMP 2	
	WRKTWTBT	RFC KU-TWTA BASEPLATE TEMP RED	
	WTWTSIDT	WBM X-TWTA SIDE TEMP	
	WKDNCONT	RFC KU DOWNCONVERTER TEMP	
	WPXCOVT	WBM +X COVER TEMP	
	WATRCVRT	WBM AUTOTRACK RCVR TEMP	
	WPSUPYT	WBM PSU TEMP (+Y PANEL)	
	WPXTWTAT	WBM X-TWTA BASEPLATE TEMP PRIME	
	WPZPNLT	WBM +Z PANEL TEMP	
	WKFST	WBM KU FREQ SOURCE TEMP	
	WXFST	WBM X-BAND FREQ SOURCE TEMP	
	WPSUMXT	WBM PSU TEMP (-X PANEL)	
	WGDET	WBM GIMBAL DRIVE ELECTRONICS TEMP	
	WRXTWTAT	WBM X-TWTA BASEPLATE TEMP RED	
	WPSKMODT	WBM UQPSK MODULATOR TEMP	
	WKTWTAT	RFC KU-TWTA SIDE TEMP	
	WPELMOTT	GDA ELEVATION MOTOR TEMP PRIME	
	WRAZMOTT	GDA AZIMUTH MOTOR TEMP REDUNDANT	
	WRIU9AT	RIU 09A TEMP	
	WRIU9BT	RIU 09B TEMP	
NBTR			
	N1EUTMP	EU TEMPERATURE	
	N1TUTMP	TU TEMPERATURE	
	N2EUTMP	EU TEMPERATURE	
	N2TUTMP	TU TEMPERATURE	
DPU			
	DPUTEMP	DPU TEMP	

*Red Low, Yellow Low, Yellow High, Red High, Delta

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Table 19.2-4. Telemetry Points, Thermal Control Subsystem (Cont'd)

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
PDU			
	YSMAHTR	TM SMA HTR PWR ENA/DISA	
	YMSHTB	MSS I/F B HTR ENA/DISA	
	YXSBYHT	TM EXT STANDBY HTR ENA/DISA	
	YU3AHTR	USS HTR 3A ENA/DISA	
	YU3BHTR	USS HTR 3B ENA/DISA	
	YHNGHTR	HINGE HEATERS ON/OFF	
	YU3CBUS	USS HTR 3C BUS A/BUS B	
	YU3CHTR	USS HTR 3C ENA/DISA	
	YTLOGIC	PDU LOGIC TEMP	
	YTPS	PDU PWR SUPPLY TEMP	
MACS			
	ATR1HTA	ACE A FHST 1 HEATER PWR OFF/ON	
	ATR2HTA	ACE A FHST 2 HEATER PWR OFF/ON	
	AHTRA1A	ACE A HEATER 1A POWER OFF/ON	
	AHTRA1B	ACE A HEATER 1B POWER OFF/ON	
	AHTRA2A	ACE A HEATER 2A POWER OFF/ON	
	AHTRA2B	ACE A HEATER 2B POWER OFF/ON	
	AHTRA3A	ACE A HEATER 3A POWER OFF/ON	
	AHTRA3B	ACE A HEATER 3B POWER OFF/ON	
	ATR1HTB	ACE B FHST 1 HEATER POWER OFF/ON	
	ATR2HTB	ACE B FHST 2 HEATER POWER OFF/ON	
	AHTRB1A	ACE B HEATER 1A POWER OFF/ON	
	AHTRB1B	ACE B HEATER 1B POWER OFF/ON	
	AHTRB2A	ACE B HEATER 2A POWER OFF/ON	
	AHTRB2B	ACE B HEATER 2B POWER OFF/ON	
	AHTRB3A	ACE B HEATER 3A POWER OFF/ON	
	AHTRB3B	ACE B HEATER 3B POWER OFF/ON	
	AXWHLTMP	ROLL SRW TEMP	26,48.157,180,0
	AYWHLTMP	PITCH SRW TEMP	26,48,157.180,0
	AZWHLTMP	YAW SRW TEMP	26,48,157.180.0

*Red Low, Yellow Low, Yellow High, Red High, Delta

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Table 19.2-4. Telemetry Points, Thermal Control Subsystem (Cont'd)

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
MACS (CONT)			
	ASWHLTMP	SKEW SRW TEMP	26,48,157,180,0
	ASTOBTMP	OPTICAL BENCH TEMP	
	APSUTMP	PSU TEMP	26,48,157,180,0
	AFSSTMP	FSS TEMP	26,48,157,180,0
	ARIU2TMP	RIU 02 TEMP	
	AAPWRCDT	ACE A POWER CONDITIONER TEMP	26,48,157,180,0
	ABPWRCDT	ACE B POWER CONDITIONER TEMP	26,48,157,180,0
	AWHDRELT	SRW DRIVE ELECTRONICS TEMP	26,48,157,180,0
	ATQDRELT	TORQ DRIVE ELECTRONICS TEMP	26,48,157,180,0
	AIRUATMP	IRU CHANNEL A TEMP	
	AIRUBTMP	IRU CHANNEL B TEMP	
	AIRUCTMP	IRU CHANNEL C TEMP	
	AIRUOBTP	OPTICAL BENCH TEMP (IRU)	
	AST1TEMP	FHST 1 TEMP	0,15,220,241,0
	AST2TEMP	FHST 2 TEMP	0,0,207,237,0
MSS			
	MTSCMRRG	SCAN MIRROR REGULATOR TEMP	51,51,236,236,0
	MTSCMREL	SCAN MIRROR ELECTRONICS TEMP	51,51,235,235,0
	MTSCMRCL	SCAN MIRROR COIL TEMP	24,24,236,235,0
	MTSCMRHG	SCAN MIRROR HOUSING TEMP	67,67,235,235,0
	MTMUX	MUX TEMP	61,61,236,236,0
	MTRADPS	PWR SUPPLY TEMP (RADIOMETER)	67,67,235,236,0
	MTELCVR	ELECTRONICS COVER TEMP (RADIOMETER)	67,67,235,235,0
	MTPPS1	PRIMARY POWER SUPPLY 1 TEMP	67,67,235,236,0
	MTPPS2	PRIMARY POWER SUPPLY 2 TEMP	67,67,235,235,0
	MTFIBOP1	FIBER OPTICS TEMP 1	84,84,236,236,0
	MTFIBOP2	FIBER OPTICS TEMP 2	84,84,235,236,0
	SAPAT	XMTR A POWER AMP TEMP	
	SBPAT	XMTR B POWER AMP TEMP	
	EES1TMP	ESA-1 TEMPERATURE	
	EES2TMP	ESA-2 TEMPERATURE	
	EES1BTMP	ESA-1 BOLOMETER TEMPERATURE	
	EES2BTMP	ESA-2 BOLOMETER TEMPERATURE	
[illegible]			
	DTS	STAR TRACK TEMP DATA	
	DST1T	TEMP DATA FROM STAR TRACK 1	
	DST2T	TEMP DATA FROM STAR TRACK 2	

*Red Low, Yellow Low, Yellow High, Red High, Delta

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Table 19.2-4. Telemetry Points, Thermal Control Subsystem (Cont'd)

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
CDH			
	CHTR1ED	HEATER 1 ENA/DISA	
	CHTR2ED	HEATER 2 ENA/DISA	
	CPMPTMP	PMP TEMP	102,102,206,206,0
	CCUATMP	STACC CU A TEMP	89,89,192,192,0
	CCUBTMP	STACC CU B TEMP	89,89,192,192,0
	CPCUTMP	PCU TEMP	102,102,206,206,0
	CTRIUA	RIU 01 A TEMP	102,102,206,206,0
	CTRIUB	RIU 01 B TEMP	102,102,206,206,0
	CTRIUAB	RIU 01 A/B INTERSPACE TEMP	102,102,206,206,0
	CTSTNTA	STINT A TEMP	89,89,206,206,0
	CTSTNTB	STINT B TEMP	89,89,206,206,0
	CTXPAB	MODULE TEMP BETWEEN XPNDRS A & B	102,102,206,206,0
	CTA610	MODULE TEMP NEAR HTR A610 THMSTAT	102,102,206,206,0
	CTA611	MODULE TEMP NEAR HTR A611 THMSTAT	102,102,206,206,0
	CTMEM03	MEM 0,3 INTERSPACE TEMP	102,102,206,206,0
	CTXPAXO	XPNDR A TCXO TEMP	30,30,113,113,0
	CTXPAPA	XPNDR A POWER AMP TEMP	25,25,113,113,0
	CTXPBXO	XPNDR B TCXO TEMP	30,30,113,113,0
	CTXPBPA	XPNDR B POWER AMP TEMP	25,25,113,113,0
	CTEXOSC	EXT OSCILLATOR CASE TEMP	45,45,112,112,0
	CTXOVEN	EXT OSC OVEN TEMP	45,45,65,65,0
SSM			
	USS1AHTR	USS HEATER 1 A ENA/DISA	
	USS1BHTR	USS HEATER 1 B ENA/DISA	
	USS1THT	USS HEATER 1 THERMOSTAT BYPASS/ENA	
	USBHTRA	DASB RAD PRIMARY HTR ENA/DISA	
	USBHTRB	DASB RAD REDUNDANT HTR ENA/DISA	
	USBTHT	DASB RAD HTR THERMOSTAT BYPASS/ENA	
	UTMMAHA	TM/MA PRIMARY HTR ENA/DISA	
	UTMMAHB	TM/MA REDUNDANT HTR ENA/DISA	
	UTMMATH	TM/MA HTR THERMOSTAT BYPASS/ENA	
	UMSAHTA	MSS I/F A PRIMARY HTR ENA/DISA	
	UMSAHTB	MSS I/F A REDUNDANT HTR ENA/DISA	
	UMSATHT	MSS I/F A HTR THERMOSTAT BYPASS/ENA	
	UW3HTRA	W3 MOD I/F PRIMARY HTR ENA/DISA	
	UW3HTRB	W3 MOD I/F REDUNDANT HTR ENA/DISA	
	UW3THT	W3 MOD I/F HTR THERMOSTAT BYPASS/ENA	
	USS2AHTR	USS HEATER 2 A ENA/DISA	
	USS2BHTR	USS HEATER 2 B ENA/DISA	
	USS2THT	USS HEATER 2 THERMOSTAT BYPASS/ENA	
	UTMHTR1	TM SAFEHOLD HTR 1 ENA/DISA	
	UTMHTR2	TM SAFEHOLD HTR 2 ENA/DISA	
	UTMTHT	TM S/H HTR THERMOSTAT BYPASS/ENA	
	UPLBAHTR	PAYLOAD HTR B PRIMARY ENA/DISA	
	UPLBBHTR	PAYLOAD HTR B REDUNDANT ENA/DISA	

*Red Low, Yellow Low, Yellow High, Red High, Delta

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Table 19.2-4. Telemetry Points, Thermal Control Subsystem (Cont'd)

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
SCCU (CONT)	UPLDTHT	PAYLOAD HTR B THERMOSTAT BYPASS/ENA	
	USCHTR1	S/C HEATER 1 ENA/DISA	
	USC1THT	S/C HEATER 1 THERMOSTAT BYPASS/ENA	
	USCHTR2	S/C HEATER 2 ENA/DISA	
	USC2THT	S/C HEATER 2 THERMOSTAT BYPASS/ENA	
	USCHTR3	S/C HEATER 3 ENA/DISA	
	USC3THT	S/C HEATER 3 THERMOSTAT BYPASS/ENA	
	USCHTR4	S/C HEATER 4 ENA/DISA	
	USC4THT	S/C HEATER 4 THERMOSTAT BYPASS/ENA	
	USCHTR5	S/C HEATER 5 ENA/DISA	
	USC5THT	S/C HEATER 5 THERMOSTAT BYPASS/ENA	
	USCHTR6	S/C HEATER 6 ENA/DISA	
	USC6THT	S/C HEATER 6 THERMOSTAT BYPASS/ENA	
	UHTRAED	SC & CU HEATER A ENABLED/DISABLED	
	UTHTABE	SC & CU THERMOSTAT A BYPASSED/ENABLED	
	UHTRBED	SC & CU HEATER B ENABLED/DISABLED	
	UTHTBBE	SC & CU THERMOSTAT B BYPASSED/ENABLED	
	UTSCCU	SC & CU TEMPERATURE	102,102,206,206,0
	UT1MMS	SPACECRAFT STRUCTURE TEMP 1	68,68,135,135,0
	UT2MMS	SPACECRAFT STRUCTURE TEMP 2	68,68,135,135,0
	UT3MMS	SPACECRAFT STRUCTURE TEMP 3	68,68,135,135,0
	UT4MMS	SPACECRAFT STRUCTURE TEMP 4	58,68,152,152,0
	UT5MMS	SPACECRAFT STRUCTURE TEMP 5	58,68,152,152,0
	UT6MMS	SPACECRAFT STRUCTURE TEMP 6	58,68,152,152,0
	UTRIUA	RIU 04A TEMPERATURE	102,102,206,206,0
	UTRIUB	RIU 04B TEMPERATURE	102,102,206,206,0

*Red Low, Yellow Low, Yellow High, Red High, Delta

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Table 19.2-4. Telemetry Points, Thermal Control Subsystem (Cont'd)

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
PM			
	ZRMAPRHT	REM A PRIMARY HEATER ON/OFF	
	ZRMBPRHT	REM B PRIMARY HEATER ON/OFF	
	ZRMCPRHT	REM C PRIMARY HEATER ON/OFF	
	ZRMDPRHT	REM D PRIMARY HEATER ON/OFF	
	ZSHFPRHT	SHELF PRIMARY HEATERS ON/OFF	
	ZRMABUHT	REM A REDUNDANT HEATER ON/OFF	
	ZRMBBUHT	REM B REDUNDANT HEATER ON/OFF	
	ZRMCBUHT	REM C REDUNDANT HEATER ON/OFF	
	ZRMDBUHT	REM D REDUNDANT HEATER ON/OFF	
	ZSHFBUHT	SHELF REDUNDANT HEATERS ON/OFF	
	ZTRMA1A3	REM A TEMP 1 (PME-A)	17,36,224,230,0
	ZTRMA2A4	REM A TEMP 2 (PME-A)	17,36,224,230,0
	ZTRMB1B3	REM B TEMP 1 (PME-A)	17,36,224,230,0
	ZTRMB2B4	REM B TEMP 2 (PME-A)	17,36,224,230,0
	ZTRMC1C3	REM C TEMP 1 (PME-A)	17,36,224,230,0
	ZTRMC2C4	REM C TEMP 2 (PME-A)	17,36,224,230,0
	ZTRMD1D3	REM D TEMP 1 (PME-A)	17,36,224,230,0
	ZTRMD2D4	REM D TEMP 2 (PME-A)	17,36,224,230,0
	ZTTANK1	TANK 1 TEMP	10,10,76,79,0
	ZTTANK2	TANK 2 TEMP	10,10,76,78,0
	ZTTANK3	TANK 3 TEMP	234,234,255,255,0
	ZTLV1LV4	L/V 1 TEMP (PME-A)	234,234,255,255,0
	ZTLV2LV5	L/V 2 TEMP (PME-A)	7,10,15,20,0
	ZTLV3LV6	L/V 3 TEMP (PME-A)	86,98,204,216,0
	ZTBMCTR	BEAM TEMP CENTER (PME-A)	
	ZTBMRMAE	BEAM TEMP REM A (PME-A)	
	ZHTRBUS	PRI/REDUND HTR BUS ENA/DISA	86,98,204,216,0
	ZPRTKHT	PM-1A PRI TANK HTR ENA/DISA	
	ZPRLNHT	PM-1A PRI LINE HTR ENA/DISA	
	ZPRLNTH	PM-1A PRI LINE HTR THMSTAT BYP/ENA	
	ZBUTKHT	PM-1A RED TANK HTR ENA/DISA	
	ZBULNHT	PM-1A RED LINE HTR ENA/DISA	
	ZBULNTH	PM-1A RED LINE HTR THMSTAT BYP/ENA	
	ZT1ATNK	PM-1A TANK TEMPERATURE	
	ZT1AFUL	PM-1A FUEL TEMPERATURE	
	ZT1ALIN	PM-1A LINE TEMPERATURE	
RIU			
	RTRIU6	RIU 06 TEMP	
	RTRIU7	RIU 07 TEMP	
	RTRIU8	RIU 08 TEMP	
	RTADS	ADS TEMP	

*Red Low, Yellow Low, Yellow High, Red High, Delta

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Table 19.2-4. Telemetry Points, Thermal Control Subsystem (Cont'd)

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
TM			
	QTTMAF1	TM ATTACH FITTING NO. 1 TEMP	
	QTTMAF2	TM ATTACH FITTING NO. 2 TEMP	
	QTTMAF3	TM ATTACH FITTING NO. 3 TEMP	
	QTTMAF4	TM ATTACH FITTING NO. 4 TEMP	
	QTAPXF1	APEX FITTING NO. 1 TEMP	
	QTAPXF2	APEX FITTING NO. 2 TEMP	
	QTAPXF3	APEX FITTING NO. 3 TEMP	
	QTPDUIB	PDU MTG PANEL (INBOARD) TEMP	
	QTPDUOB	PDU MTG PANEL (TOP OUTBOARD) TEMP	
	QTRIU6I	RIU 06 MOUNTING PANEL (INBOARD) TEMP	
	QTRIU6O	RIU 06 MOUNTING PANEL (OUTBOARD) TEMP	
	QTRFCPO	RF COMBINER PANEL (OUTBOARD) TEMP	
	QTEQPP1	EQUIP MTG PNL 1 TEMP (+Y)	
	QTEQPP2	EQUIP MTG PNL 2 TEMP (+Y)	
	QTEQPP3	EQUIP MTG PNL 3 TEMP (+Y)	
	QTEQPN4	EQUIP MTG PNL 4 TEMP (-Y)	
	QTEQPN5	EQUIP MTG PNL 5 TEMP (-Y)	
	QTEQPN6	EQUIP MTG PNL 6 TEMP (-Y)	
	QTSBXP1	S-BAND XMTR PNL NO. 1 TEMP	
	QTSBXP2	S-BAND XMTR PNL NO. 2 TEMP	
	QTYBKHD	-Y BULKHEAD TEMP	
	QTCWWB1	CLOSING WEB (WB MODULE) NO. 1 TEMP	
	QTCWWB2	CLOSING WEB (WB MODULE) NO. 2 TEMP	
	QTSADPL	SAD MOUNTING PANEL TEMP	
	QTBJPYO	BOOM JETTISON PYRO BRACKET TEMP	
	QTMSSMT	MSS MOUNT TEMP	
	QTMSSW1	CLOSING WEB (MSS SENSOR) NO. 1 TEMP	
	QTMSSW2	CLOSING WEB (MSS SENSOR) NO. 2 TEMP	
	QTUBPWH	BOOM UPPER PWR HINGE LOWER HALF	
	QTLBPWHI	BOOM ROOT PWR HINGE LOWER HALF	
	QTGPSAP	GPS AMPLIFIER TEMP	
	QTPOSYK	+Y KEEL STRUCTURE TEMP	
	QTNEGYK	-Y KEEL STRUCTURE TEMP	
	QTBLF1	BOOM LATCHDOWN FITTING TEMP NO. 1	
	QTBLF2	BOOM LATCHDOWN FITTING TEMP NO. 2	
	QTLBPWH	BOOM ROOT PWR HINGE UPPER HALF	
	QTUBIF	UPPER BOOM AT GDA I/F	
	QTARRY1	ARRAY TEMP NO. 1	
	QTARRY2	ARRAY TEMP NO. 2	
	QTARRY3	ARRAY TEMP NO. 3	
	QTARRY4	ARRAY TEMP NO. 4	

*Red Low, Yellow Low, Yellow High, Red High, Delta

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Table 19.2-4. Telemetry Points, Thermal Control Subsyste (Cont'd)

Subsystem, Module, Instrument	Mnemonic	Description	Limit*
TM	TBBT	BLACKBODY TEMPERATURE	48,48,226,226,0
	TSIFPT	SILICON FOCAL PLANE TEMP	10,10,254,254,0
	TCALST	CAL SHUTTER TEMP	4,4,227,227,0
	TBUST	BACK-UP SHUTTER TEMP	4,4,227,227,0
	TCSCT	COLD STAGE TEMP A (COLD)	0,0,213,213,0
	TCSHT	COLD STAGE TEMP B (HOT)	1,1,195,195,0
	TISCT	INTEMEDIATE STAGE TEMP A	0,0,250,250,0
	TISHT	INTEMEDIATE STAGE TEMP B	1,1,209,209,0
	TCFPACT	COLD FOCAL PLANE ASSY CNTRL TEMP	0,0,250,250,0
	TBAFFT	BAFFLE TEMP	14,14,244,244,0
	TCFPAMT	COLD FOCAL PLANE ARRAY MONITOR TEMP	0,0,250,250,0
	TAOPAT	AMB ODD PREAMP TEMP	57,57,242,242,0
	TCPAT	COLD PREAMP TEMP	96,96,254,254,0
	TROT	RELAY OPTICS TEMP	96,96,242,242,0
	TPST	PWR SUPP TEMP	68,68,242,242,0
	TB5PAT	BAND 5 POST AMP TEMP	68,68,242,242,0
	TMUXET	MULTIPLEXER ELEC TEMP	27,27,166,166,0
	TMUXPST	MULTIPLEXER PWR SUPP TEMP	27,27,166,166,0
	TLMPDRT	CAL LAMP DRIVER TEMP	68,68,242,242,0
	TPMT	PRI MIRROR TEMP	108,108,233,233,0
	TPMMT	PRI MIRROR MASK TEMP	108,108,233,233,0
	TSMT	SECONDARY MIRROR TEMP	108,108,233,233,0
	TSMMT	SECONDARY MIRROR MASK TEMP	108,108,233,233,0
	TAEPAT	AMB EVEN PRE-AMP TEMP	57,57,242,242,0
	TTHT	TELESCOPE HOUSING TEMP	108,108,233,233,0
	TTBPT	TELESCOPE BASEPLATE TEMP	108,108,233,233,0
	TCALSHT	CAL SHUTTER HUB TEMP	109,108,242,242,0
	TDWNSMT	SMA +Z HOUSING TEMP	68,68,149,149,0
	TUPSMT	SMA -Z HOUSING TEMP	68,68,149,149,0
	TSAMT	SCAN ANGLE MONITOR TEMP	56,56,228,228,0
	TSMAET	SMA ELEC TEMP	56,56,228,228,0
	TFWDSMT	SMA +X FLEX PIVOT TEMP	68,68,149,149,0
	TAFTSMT	SMA -X FLEX PIVOT TEMP	68,68,149,149,0
	TSST	SUNSHIELD TEMP	56,56,184,184,0
	TSLCT	TEMP	68,68,149,149,0
	TLMPFT	C. AMP FILTER TEMP	29,29,254,254,0
	TCAST	COOLER AMP STAGE TEMP	56,56,254,254,0
	TCDT	COOLER DOOR TEMP	55,55,254,254,0
	TRFINT	+Y RADIATOR FIN TEMP	37,37,254,254,0
GPS	GOSCOVNT	OSCILLATOR OVEN TEMP	60,60,67,67,0
	GOSCCAST	EXTERNAL OSC CASE TEMP	80,80,175,175,0
	GALCAMDT	R/PA ANALOG MODULE TEMP	80,80,175,175,0
	GPRIAMPT	EXTERNAL PREAMP TEMP	80,80,175,175,0

*Red Low, Yellow Low, Yellow High, Red High, Delta

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20.0 SOLAR ARRAY RETENTION DEPLOYMENT AND JETTISON ASSEMBLY

SECTION 20.0

SOLAR ARRAY RETRACTION, DEPLOYMENT, AND JETTISON ASSEMBLY (SARDJA)

20.1 FUNCTIONAL DESCRIPTION

The major items of the SARDJA are as follows:

1. Solar Array Wing Assembly Installation
2. Ordnance Activated Device
3. Solar Array Wing Assembly
    a. Solar Panel Retention Assembly
    b. Solar Array Hinge Assembly
    c. Sync Cable Assembly and Installation
    d. Solar Array Jettison Assembly
    e. Power Hinge Assembly
    f. Power Hinge Module

See Figure 20.1-1 for location of solar array related mechanisms, and Table 20.1-1 for a list of SARDJA functions.

20.1.1 MECHANICAL

The SARDJA interfaces mechanically with the Instrument Module (IM) structure, the Solar Array Drive and Power Transfer Assembly (SADAPTA), and the solar array panels.

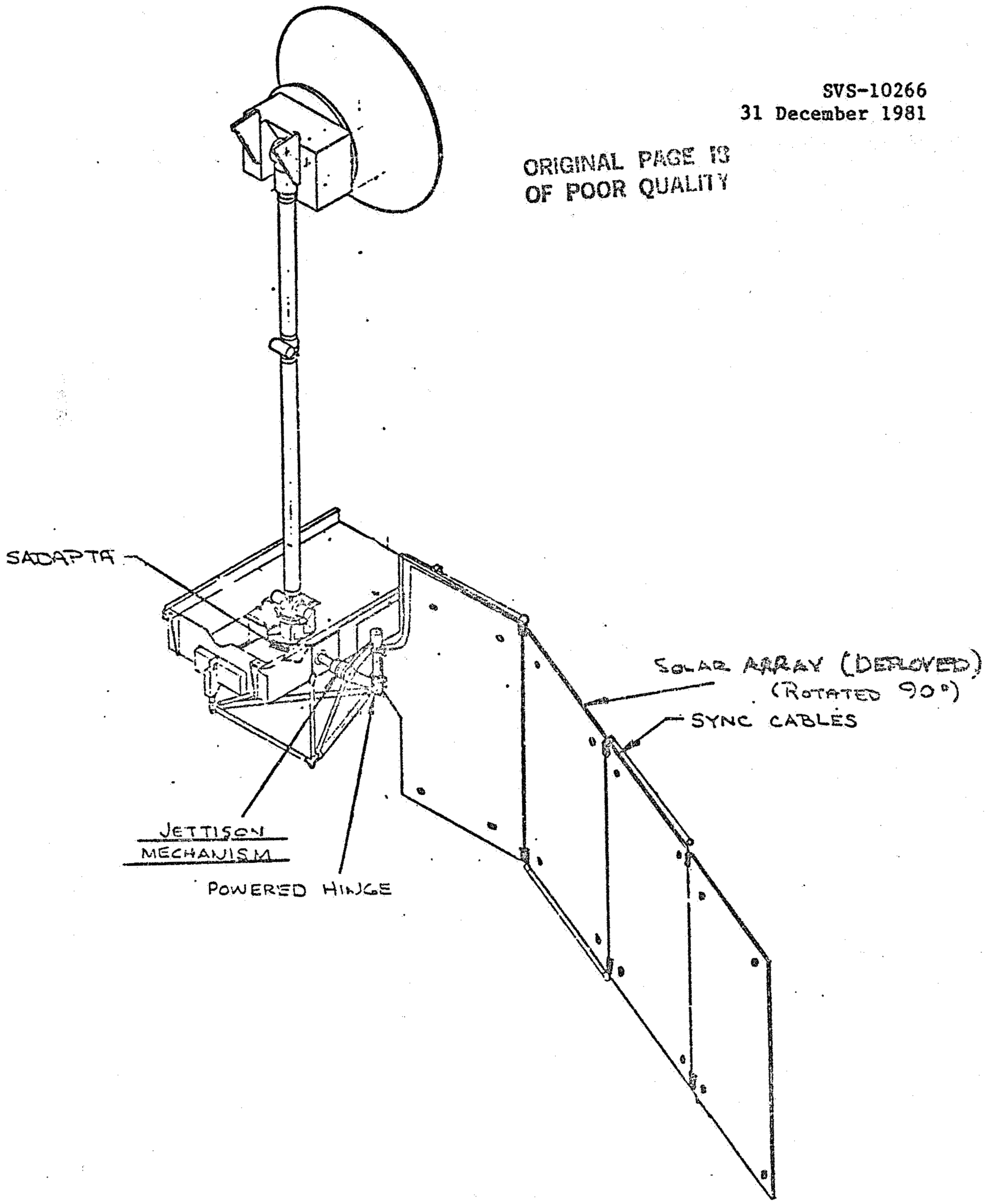

Figure 20.1-1. Solar Array-Related Mechanisms Locations

Table 20.1-1. SARDJA Functions

Function	Performed By	Interface
RETAIN Solar Array to Instrument Module structure in stowed configuration within launch vehicle fairing dynamic envelope	Separation Nuts & Bolts	Instrument Module Structure
RELEASE Solar Array from Instrument Module structure	EED's	Signal Conditioning & Control Unit
DEPLOY Solar Array to and RETAIN in orbital operating position	Hinges Springs Sync Cables Power Hinge	Power Distribution Unit
JETTISON Solar Array by mechanical and electrical separation	EED's Separation Nut V Band Elect Discon Spring	Signal Conditioning & Control Unit

20.1.2 ELECTRICAL

The SARDJA interfaces electrically with: 1) the Signal Conditioning and Control Unit (SC&CU) in the MMS (which provides power to energize the separation nuts) and 2) the Power Distribution Unit (PDU) which provides power and controls the power hinge for deployment, and 3) the SADAPTA (through which all electrical interface circuits pass).

20.2 PERFORMANCE CAPABILITIES

20.2.1 RETENTION

The SARDJA retains the Solar Array Wing Assembly to the IM structure in the stowed position with separation nuts and bolts at four places.

20.2.2 RELEASE

Activation of the EED (separation nut) retention devices does not generate mechanical debris nor does it emit gaseous products of combustion. An enclosed gas driven piston spreads a segmented captive nut, thereby allowing release of the solar array panels. The retention device has been designed to minimize the shock imparted to the spacecraft at release of the solar array panels.

20.2.3 DEPLOYMENT

20.2.3.1 Control

Deployment is effected by the continuous application of electrical power from the PDU to either motor of the power hinge.

20.2.3.2 Stops

Position stops are provided at each hinge axis of rotation to limit panel travel. Each stop is capable of surviving the resultant forces without permanent deformation as the array panels reach the deployed position. Two switches indicate when the Power Module hinge line has reached the stop position and then a pulse count is begun. After 2048 pulses by the PDU, electrical power to the Power Hinge motor is terminated.

20.2.3.3 Preload

In the deployed position, the Power Hinge stops are maintained in contact by a minimum hinge line torque of 100 in-lb. All other stops are maintained in contact by a minimum hinge line moment of 20 in-lb.

20.2.3.4 Synchronization

All panel hinge motions are synchronized and controlled by passive mechanical devices so as to preclude any possibility of the array striking the spacecraft during deployment.

20.2.3.5 Deployment Torque

Deployment torque at each hinge line is supplied redundantly. Multiple torsion springs apply torque directly to the outboard panels, and the Power Hinge is capable of supplying the required torque to the Hinge Lines through the synchronization devices. Delivered torque is a minimum of two times the budgeted friction torque which the Power Hinge is required to overcome at each hinge line.

20.2.3.6 Rate Control

Power Hinge Motor speed combined with synchronization is used to control the deployment rate and to satisfy deployment time requirements (paragraph 20.2.3.7).

20.2.3.7 Deployment Time

The elapsed time from application of power from the PDU until all panels are deployed against their stops does not exceed 20 minutes over the planned range of operating temperatures in a vacuum environment.

20.2.4 JETTISON

20.2.4.1 Solar Array Separation

Mechanical and electrical separation of the Solar Array from the spacecraft are initiated by means of an EED at the separation plane.

20.2.4.2 Solar Array Jettison

Coincident with separation, the solar array is jettisoned from the spacecraft at a minimum velocity of 1.0 ft/sec. The jettison force, provided by a compressed spring, is designed to minimize tumbling of the array (i.e., force vector is thru the CG of the Solar Array) as it separates from the spacecraft.

20.3 MODES OF OPERATION

Launch Mode	-	SA retained (Stowed)
Orbit Mode	-	SA being deployed (Deployment)
Orbit Mode	-	SA deployed (Operating)
Orbit Mode	-	SA Jettison: SA separated from spacecraft at minimum velocity of 1 ft/sec

See Figure 20.3-1 for solar array deployment.

20.4 CONSTRAINTS

The retention release firing pulse shall be applied simultaneously to diametrically opposed pairs of EED's. The second pair of EED's must be fired within five seconds of the first pair. After issuance of a firing signal to a pair of EED's, cartridges must fire within 5 ms of one another. Each separation nut has two EED cartridges which must be fired simultaneously.

20.5 REDUNDANCY

The release of the Solar Array Panels is accomplished by a completely redundant system. All of the EED's for the separation nuts employ redundant cartridges (two/nut), and the power modules are redundant (motors and speed reducers, harnesses).

20.6 COMMANDS

Description of SARDJA commands to be found in the PDU Command Directory, Section 11.6.

20.7 TELEMETRY

Description of SARDJA telemetry to be found in the PDU Telemetry Directory, Section 11.7.

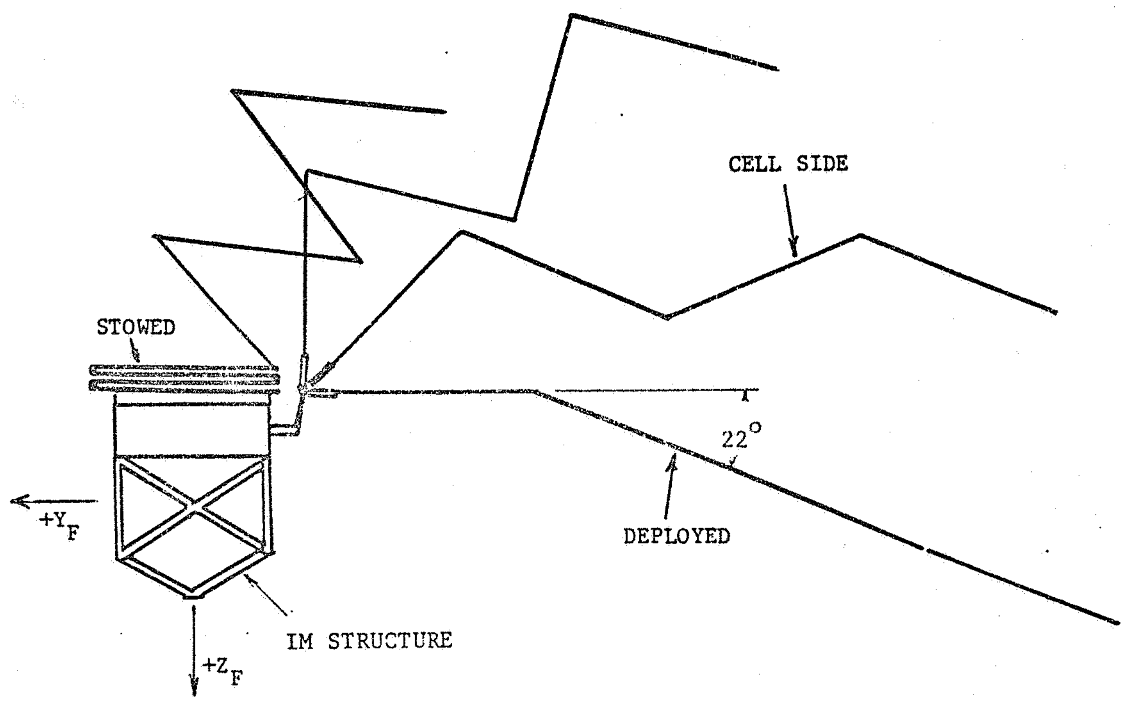

Figure 20.3-1.

SOLAR ARRAY DEPLOYMENT STAGES

21.0 BOOM ANTENNA RETENTION, DEPLOYMENT AND JETTISON ASSEMBLY

SECTION 21.0

BOOM ANTENNA RETENTION DEPLOYMENT AND JETTISON ASSEMBLY (BARDJA)

21.1 FUNCTIONAL DESCRIPTION

The major items of the BARDJA are as follows:

- High Gain Antenna
- Boom Assembly
- Power Hinge Module
- GPS Support Structure
- Cable Cutter
- Ordnance Actuated Device

See Figure 21.1-1 for location of boom antenna related mechanisms and Figure 21.1-2 for the subsystem block diagram.

The functions performed by the BARDJA components are shown below in Table 21.1-1.

Table 21.1-1. BARDJA Functions

FUNCTION	PERFORMED BY	INTERFACE
RETAIN Antenna Boom to Instrument Module structure in stowed configuration within launch vehicle fairing	Retention/release Mechanism separation nut and bolt	Instrument Module Structure
LOCK OUT TDRSS antenna gimbal bearings during launch	Launch lock brackets separation nuts and bolts	TDRSS RF compartment
RELEASE Antenna Boom from Instrument Module structure, and launch lock	EED's	Signal Condit-ioning & Control Unit
DEPLOY Antenna Boom and RETAIN in orbital operating position	Power Hinges	Power Distribution Unit
SUPPORT Antennas	Boom Structure Antenna Support Structure	TDRSS Gimbal GPS Antenna
JETTISON Antenna Boom by mechanical and electrical separation	EED's Separation Nut V Band Elect. Discon. Springs	Signal Conditioning & Control Unit Instrument Module Structure

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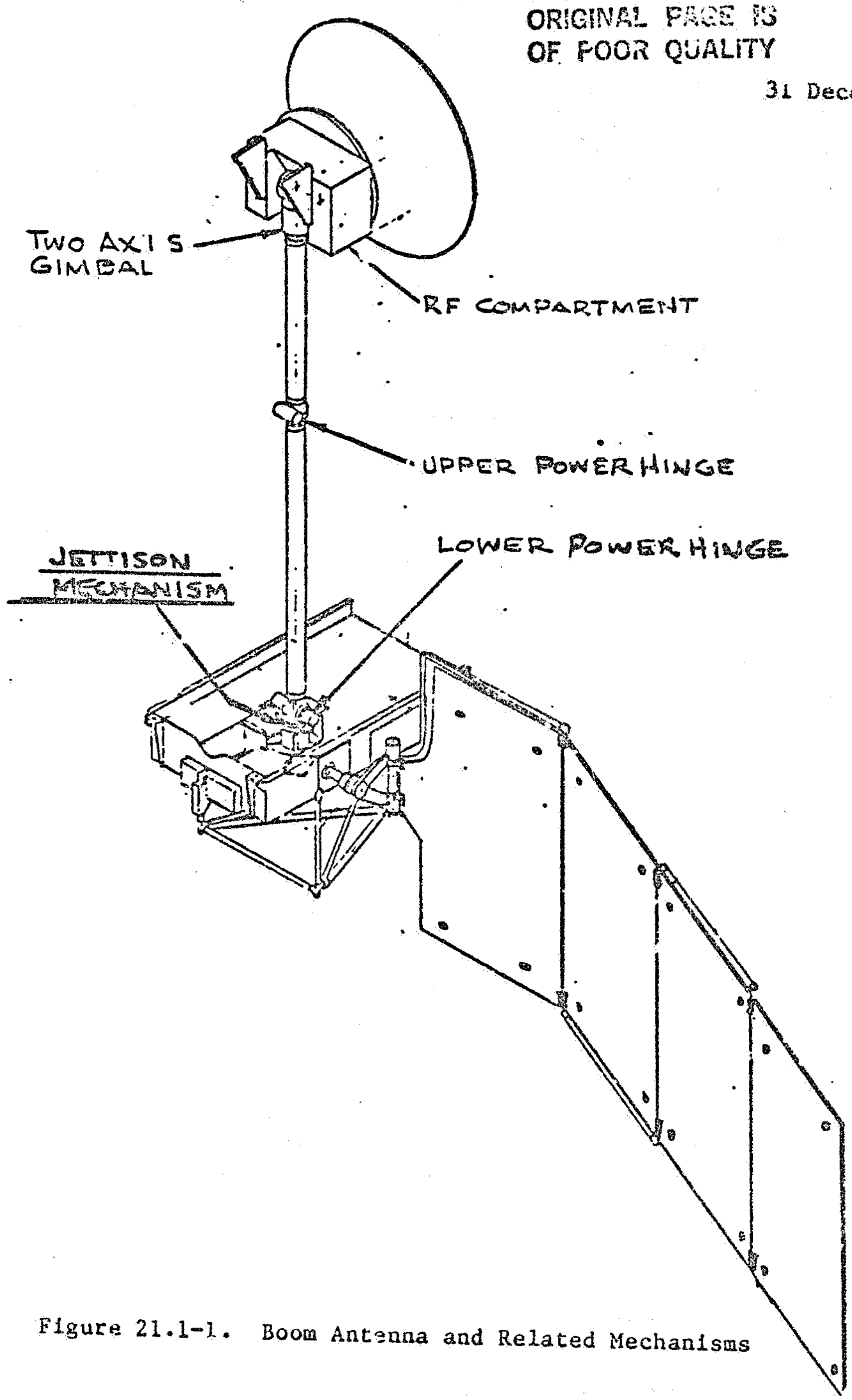

Figure 21.1-1. Boom Antenna and Related Mechanisms

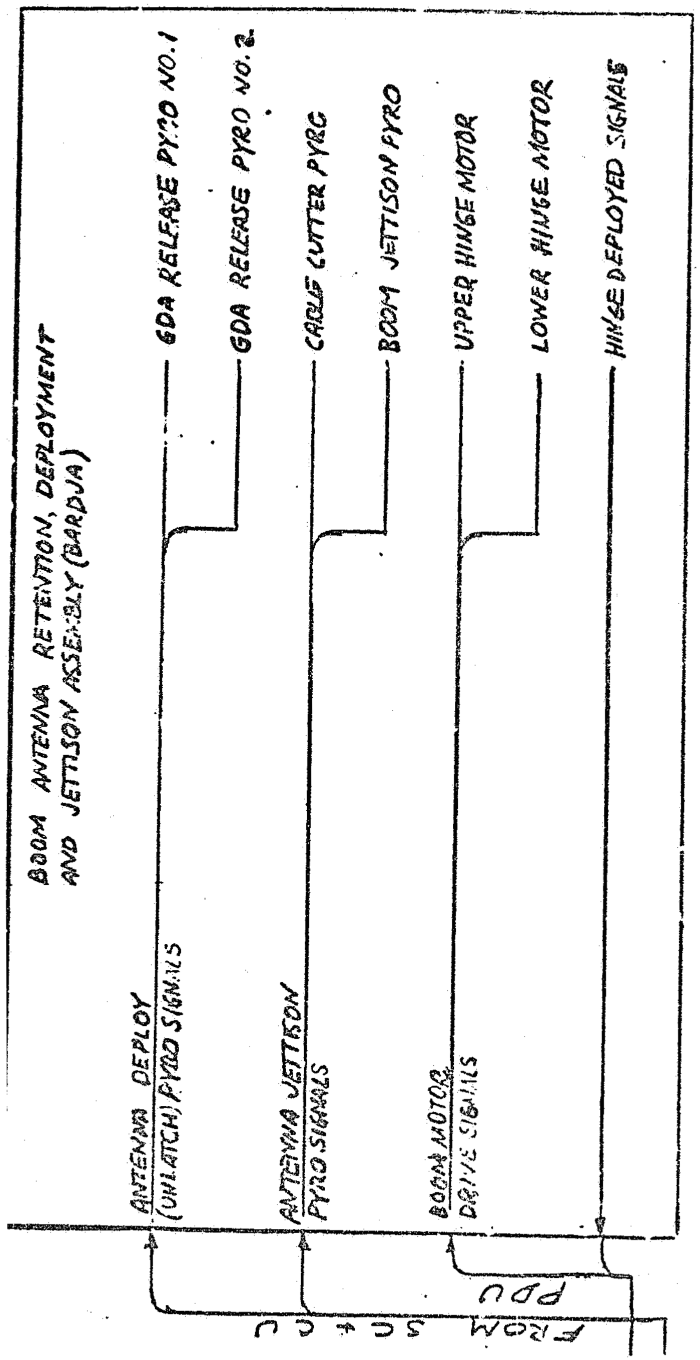

Figure 21.1-2. BARDJA Subsystem Block Diagram

21.1.1 INTERFACE DEFINITION

21.1.1.1 Mechanical

The BARDJA interfaces mechanically with the Instrument Module (IM) Structure, the Global Positioning System (GPS) antenna and pre-Amp/filter, the wideband communication RF compartment and the antenna gimbal drive of the Wide Band Communications System (WBCS).

21.1.1.2 Electrical

The BARDJA interfaces electrically with the S· ıal Conditioning and Control Unit (SC&CU) in the MMS (which provides power to ‹ . ·gize the separation nuts) and the Power Distribution Unit (PDU) (which · ·des power and controls the power hinge for deployment). The electrical circ·ı, ɔf the Global Positioning System and the Wide Band Communications System us· the BARDJA as a conduit only.

21.2 PREFORMANCE CAPABILITIES

21.2.1 RETENTION

The BARDJA retains the Boom to the IM structure in the stowed position in order to withstand transportation and launch loads.

21.2.2 LOCKOUT

The Boom secures the RF compartment in the stowed position to withstand the loads in a manner to limit tne mean Hertzian stresses in the bearing races of the Gimbal Drive Assembly (GDA) to 386 ksi., and the maximum ball contact ellipse to a shoulder override not exceeding 17 percent.

21.2.3 RELEASE

The release method of the boom retention and the GDA launch lock generates no loose mechanical debris and retains gaseous products of combustion. The release minimizes the shock imparted to the spacecraft experiments.

21.2.4 DEPLOYMENT

21.2.4.1 Control

Deployment is effected by the continuous application of electrical power from the PDU to either motor of the Power Hinges.

21.2.4.2 Stops

Position stops are provided at each hinge axis of rotation to limit the travel in the deployment direction. Each stop is capable of surviving the resultant forces with no permanent deformation as the boom segments reach the deployed position. The boom maintains its deployed position while pulsed thrusters impart linear accelerations of 2.6 in/sec^2 along the X axis and angular accelerations of 0.00128 radians/sec^2 about the Y axis with the total spacecraft weight of 3444 pounds. A switch indicates that the Power Module hinge line has reached the stop position and initiates the counting of 1024 pulses to be supplied, at which time the electrical power to the hinge motor is terminated.

21.2.4.3 Preload

In the deployed position, the Power Hinge stops are maintained in contact by a minimum hinge line torque of 300 in. lb.

21.2.4.4 Deployment Torque

Deployment torque at each hinge line is a minimum of two times the budgeted friction and the elastic torque it is required to overcome at each hinge line at the operating temperatures in a vacuum environment.

21.2.4.5 Deployment Time

The cumulative operating time from application of power from the PDU until both boom segments are deployed against their stops does not exceed 20 minutes.

21.2.5 ANTENNA SUPPORT

21.2.5.1 Wideband Communications Subsystem (WBCS)

The boom supports the WBCS RF compartment and antenna for operation through the gimbal drive assembly.

21.2.5.2 Global Positioning System

The boom shall support the GPS antenna and preamplifier.

21.2.6 JETTISON

21.2.6.1 Boom Disconnect

Mechanical and electrical separation of the boom from the spacecraft are initiated by means of an EED at the separation plane. Wires to the EED's which do not pass through the mechanical disconnects are severed to effect separation.

21.2.6.2 Boom Jettison

Coincident with separation, the boom is jettisoned from the spacecraft with a minimum velocity of 1.0 ft/sec. The jettison force direction is thru the boom CG to minimizes tumbling of the boom as it separates from the spacecraft.

21.3 MODES OF OPERATIONS

The modes of operation are retain, deploy, operate and jettison. Table 21.1-1 describes the BARDJA functions and Figure 21.3-1 illustrates the deployment sequence.

21.4 CONSTRAINTS

1. After mast deployment and attitude stabilization, release launch lock.

2. Activate Gimbal Drive Electronics and verify azimuth and elevation angles by telemetry.

3. Azimuth angle should be stow position (azimuth resolver reading 200 ±TBD degrees, refer to LD91107). If deployment shock has displaced azimuth, slew to 200 degrees resolver position by command and re-verify.

4. Command elevation within software stop (less than 118.5 degrees resolver position). Note: GDA can be stowed beyond the software stop manually; antenna pointing software will allow commanding out of stop but not return beyond stop.

21.5 REDUNDANCY

The boom separation nuts (EED) can be activated by redundant power cartridges which receive independent simultaneous firing pulses. Deployment of the boom is effected by either of two redundant motors at each of the Power Hinges.

21.6 COMMANDS

BARDJA commands will be explained in the PDU Command Directory.

21.7 TELEMETRY

BARDJA telemetry will be explained in the PDU Telemetry Directory.

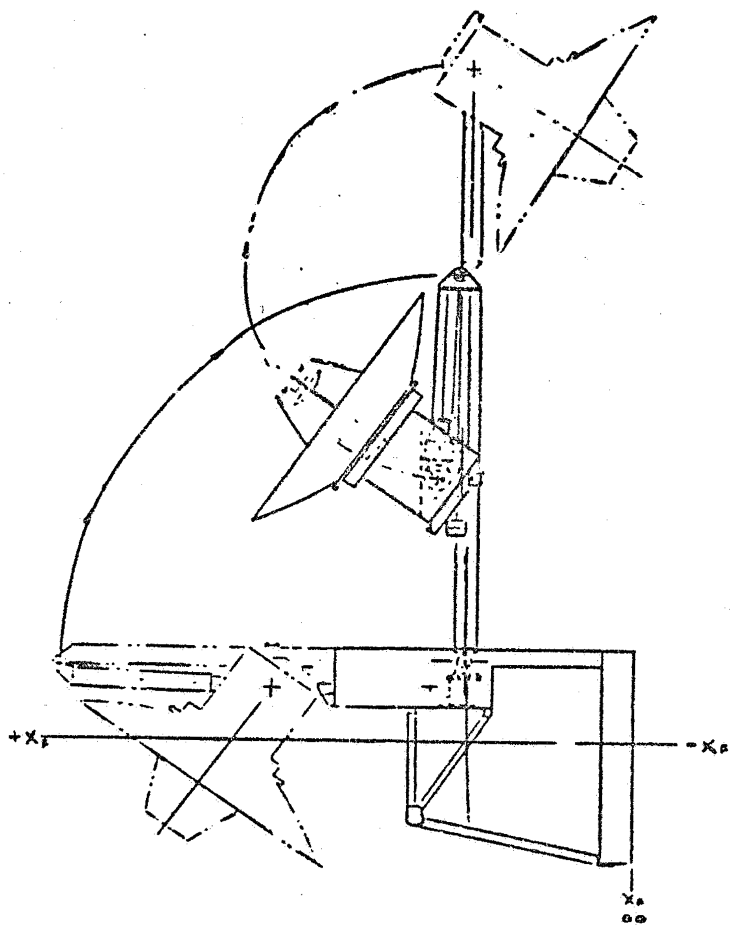

Figure 21.3-1. View Showing TDRSS Antenna Deployment

22.0 STRUCTURES

SECTION 22.0

STRUCTURE

The Landsat-D Flight Segment Structural Subsystem consists of the basic structural members required to form a flightworthy spacecraft framework. The Structural Subsystem will exist in three configurations: launch, operational, and recovery. In the launch configuration, the spacecraft will be enclosed within the shroud of a Delta 3920 booster; in the operational configuration, an antenna boom (with antennas) will be deployed as well as a set of fold-out solar panels. In the recovery configuration, the antenna boom (with antennas) and the solar panels will have been jettisoned to make ready for capture and subsequent stowage in the cargo bay of the Space Shuttle. Figure 22-1 gives a general view of the flight segment in its operational configuration.

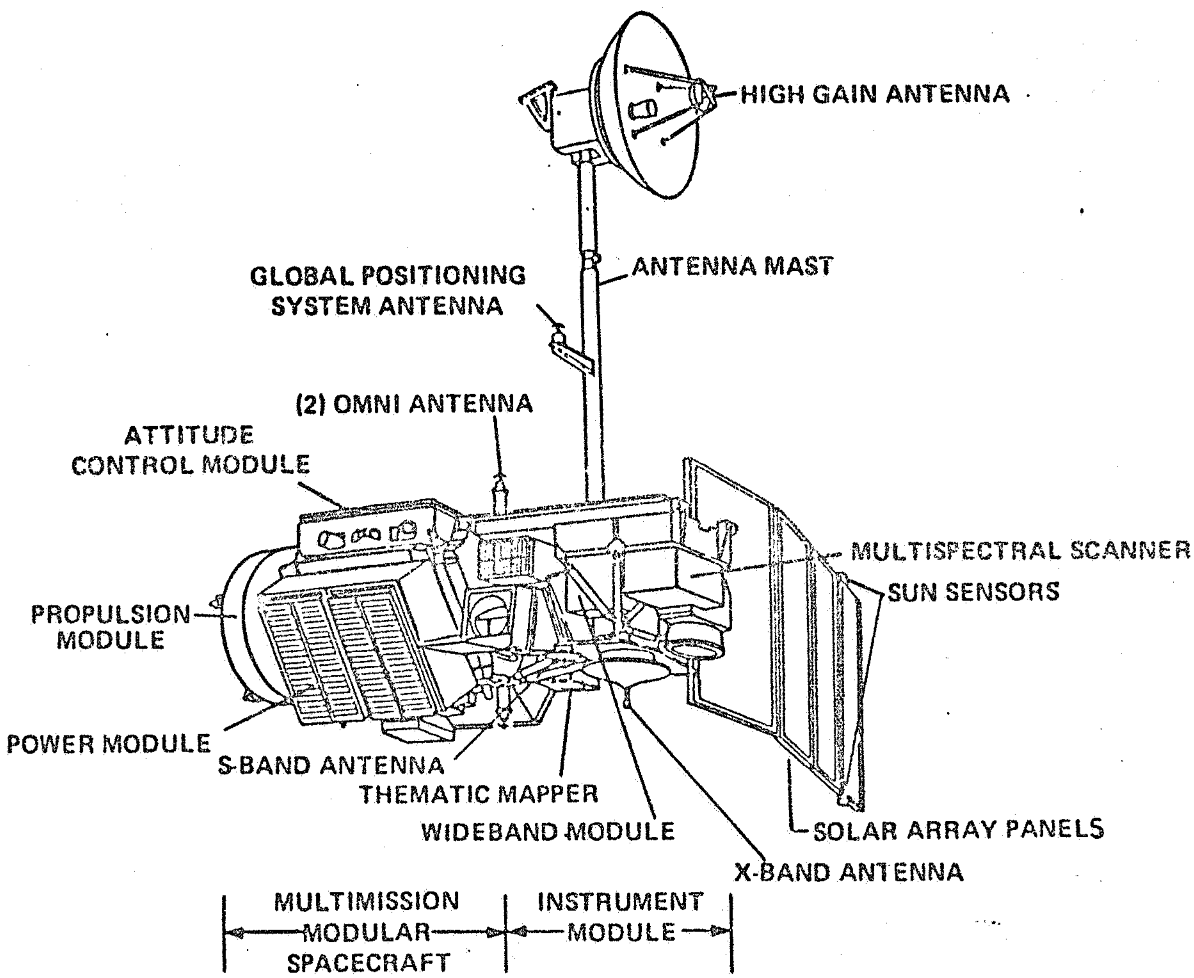

Figure 22-1. Landsat-D Flight Segment Orbital Configuration

22.1 FUNCTIONAL DESCRIPTION

The Landsat-D Flight Segment structure provides the support and housing necessary to position and protect the components of the various flight segment subsystems during test, pre-launch, launch, orbital, and recovery operations. In addition, it provides the reference planes and axes used for defining the flight segment coordinate system; provides the mounting surfaces for components, mechanisms, and equipment, and maintains the alignment of the components; and provides the routing paths, attachment points, and interface connector mounts for the electrical signal and power harnesses.

The Flight Segment is composed of the following major structural elements: (1) Instrument Module primary structure, (2) MMS support structure, (3) solar array substrate, and (4) TDRSS antenna boom. The first structural element, the IM primary structure, is further divided into three parts: the upper support structure, the mission adapter, and the truss assembly. The second structural element, the MMS support structure, includes the Triangular Transition Adapter.

The Instrument Module primary structure, with its three component parts, is shown in Figure 22.1-1. The upper support structure, shown separately in Figure 22.1-2, serves a number of purposes: (1) it provides the structure onto which most of the IM subsystems are mounted, and protects the components which are mounted within its compartments; (2) it provides for stowage of the TDRSS antenna boom and solar array assembly; (3) it provides for heat dissipation through its perforated upper panels; (4) it provides one of the two points by which the IM is lifted; and (5) it provides structural continuity between its storage compartments and the Mission Adapter. Removable panels in the upper support structure allow access to interior mounted components during test and pre-launch operations. Figure 22.1-3 shows the location of components mounted within the upper support structure.

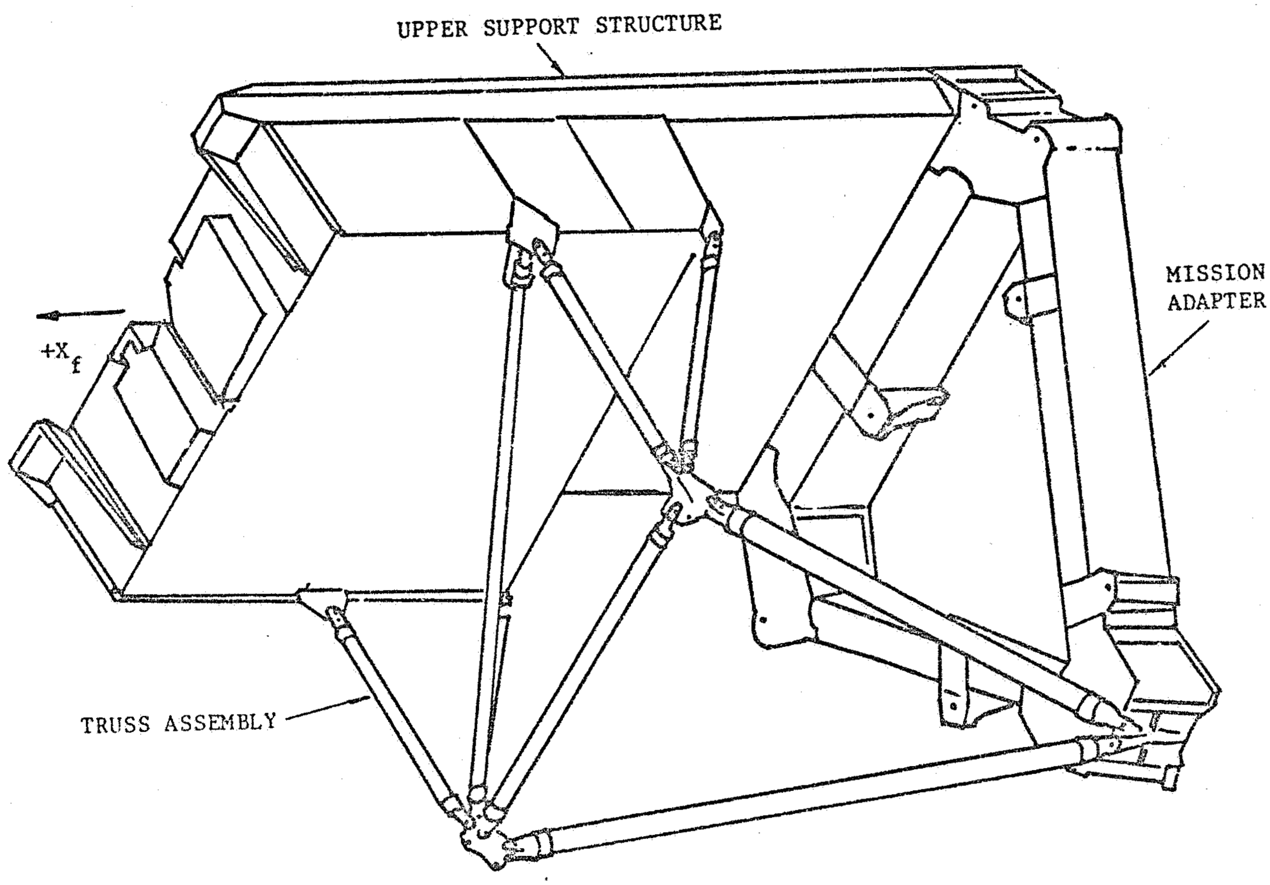

Figure 22.1-1. Instrument Module Primary Structure

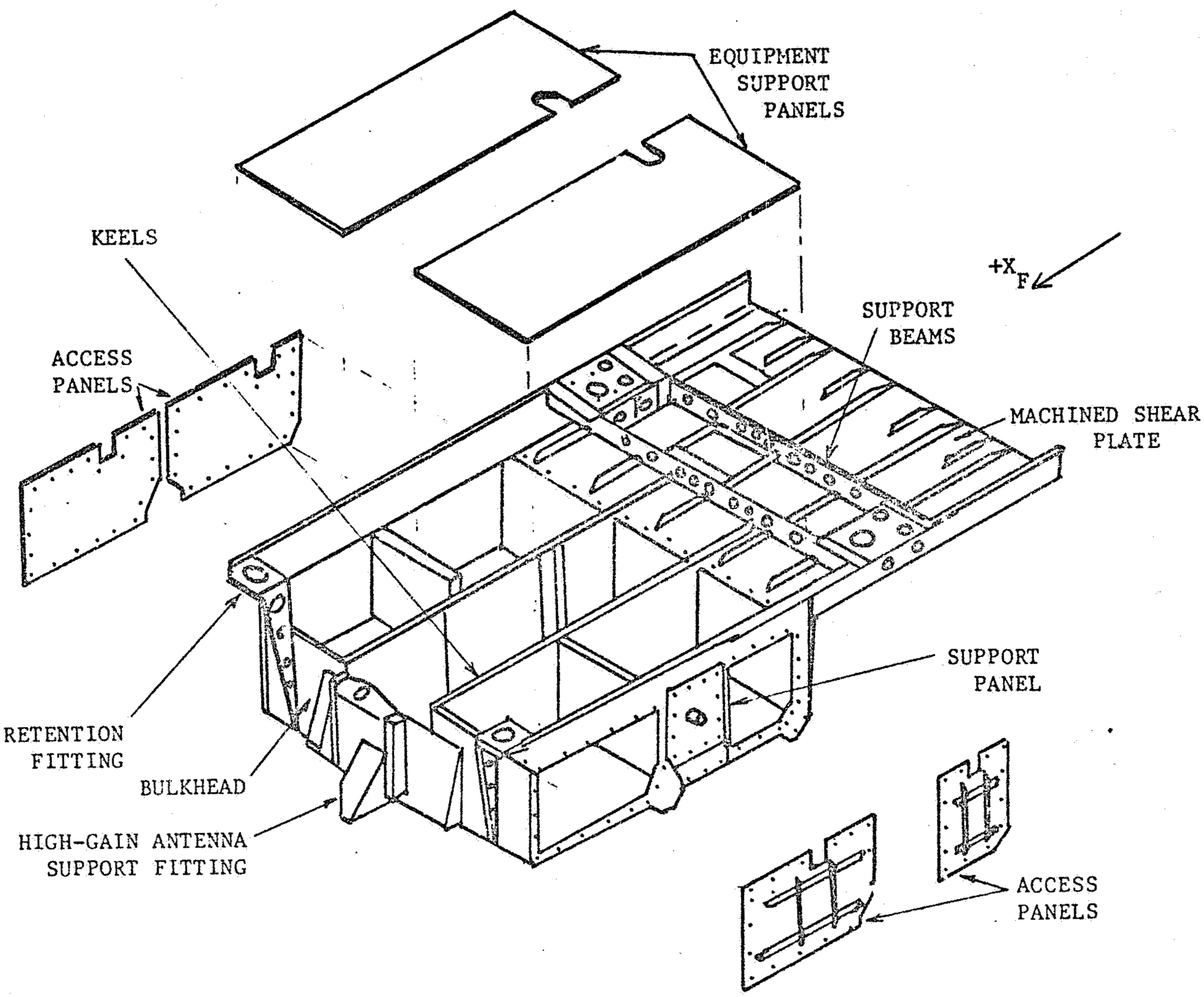

Figure 22.1-2. Upper Support Structure

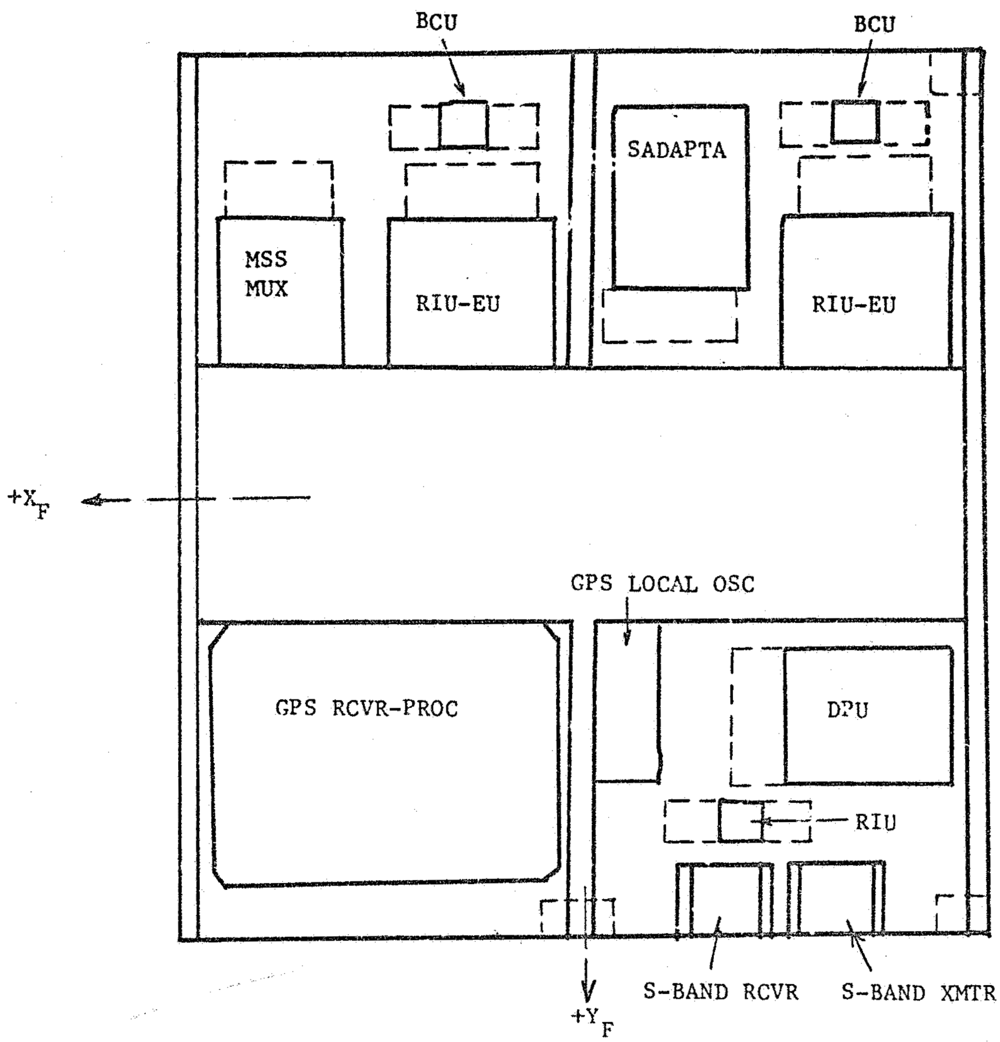

Figure 22.1-3. Component Packaging, Upper Support Structure

The Instrument Module is joined to the MMS by means of the Mission Adapter. The Mission Adapter is designed to mate with the Triangular Transition Adapter of the MMS. The Mission Adapter also provides mounting surfaces for the Power Distribution Unit (PDU), two Remote Interface Units (RIU), and one Expander Unit (EU). See Figure 22.1-4 for the location of the mounted components and for the location of the points at which the Mission Adapter is attached to the Triangular Transition Adapter, the IM upper support structure, and the IM truss.

The third component of the IM primary structure, the truss, completes the structural design of the IM portion of the Flight Segment. It ties the end of the upper support structure to the end of the Mission Adapter, allowing space for the Thematic Mapper. It also provides the second point for lifting the IM. The truss assembly is shown as part of the IM primary structure in Figure 22.1-1.

The second major structural element of the Flight Segment is the MMS support structure. It provides mounting surfaces for the various MMS subsystems as well as routing paths for electrical interconnections. The MMS support structure includes the Triangular Transition Adapter, to which the Mission Adapter of the IM is attached. Figure 22.1-5 is an exploded view of the MMS, and shows the support structure, Triangular Transition Adapter, and the MMS subsystems.

The Solar Array Substrate is the third major element of the Flight Segment structure. It forms the base onto which the solar cell arrays are attached, and supports them under the varying load conditions of test, launch, deployment, and orbital operations. The substrate provides a structure upon which two of the coarse sun sensors are mounted. The solar array is folded in a stowed position during launch, deployed for orbital operations, and jettisoned prior to the recovery of the Flight Segment by the Space Transportation System. The solar array is shown in its deployed position in Figure 22-1; Figures 22.1-6 and 22.1-7 show the arrray in its stowed position and at several stages during deployment.

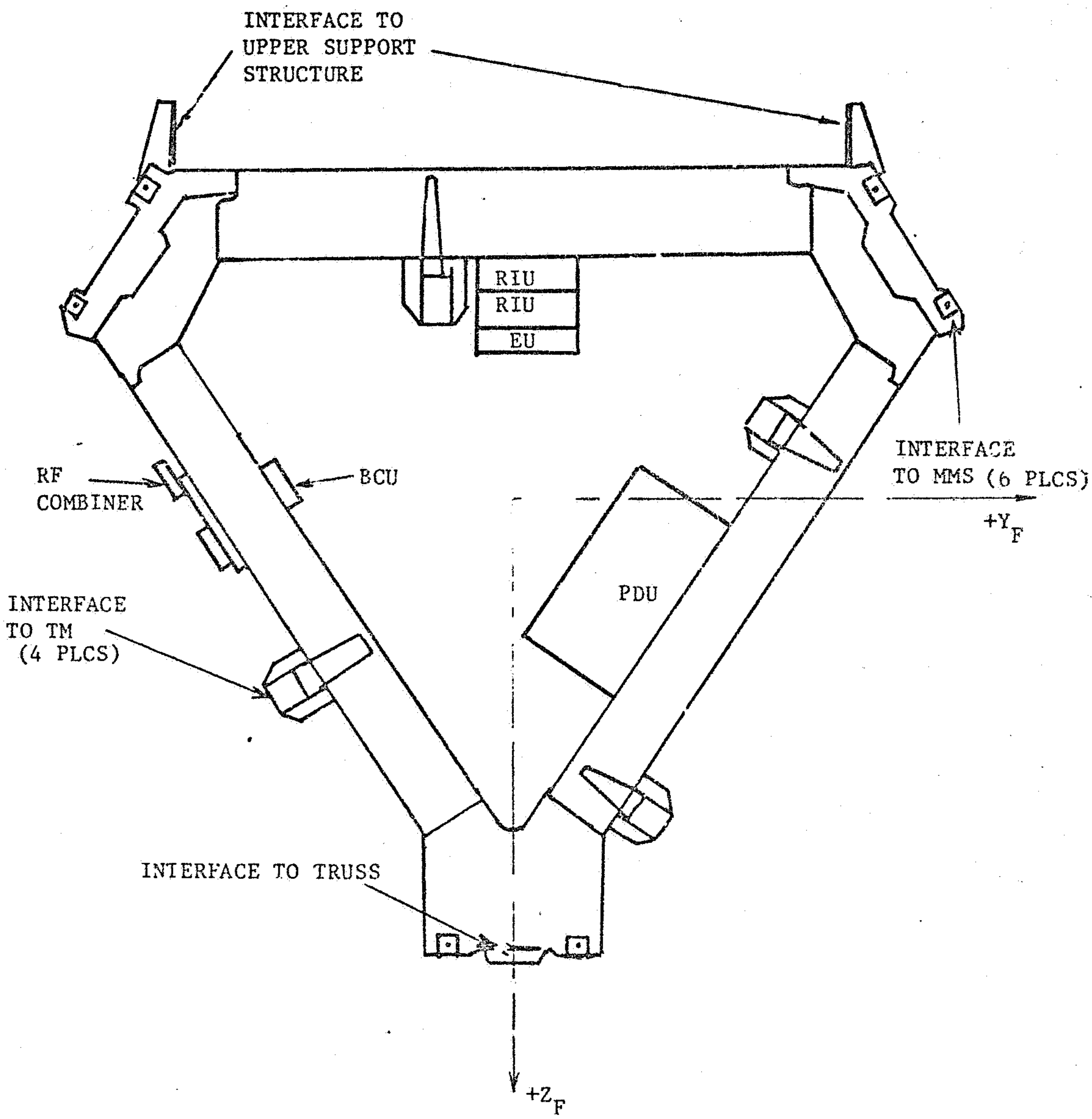

Figure 22.1-4. Component Packaging and Attachment Points, Mission Adapter

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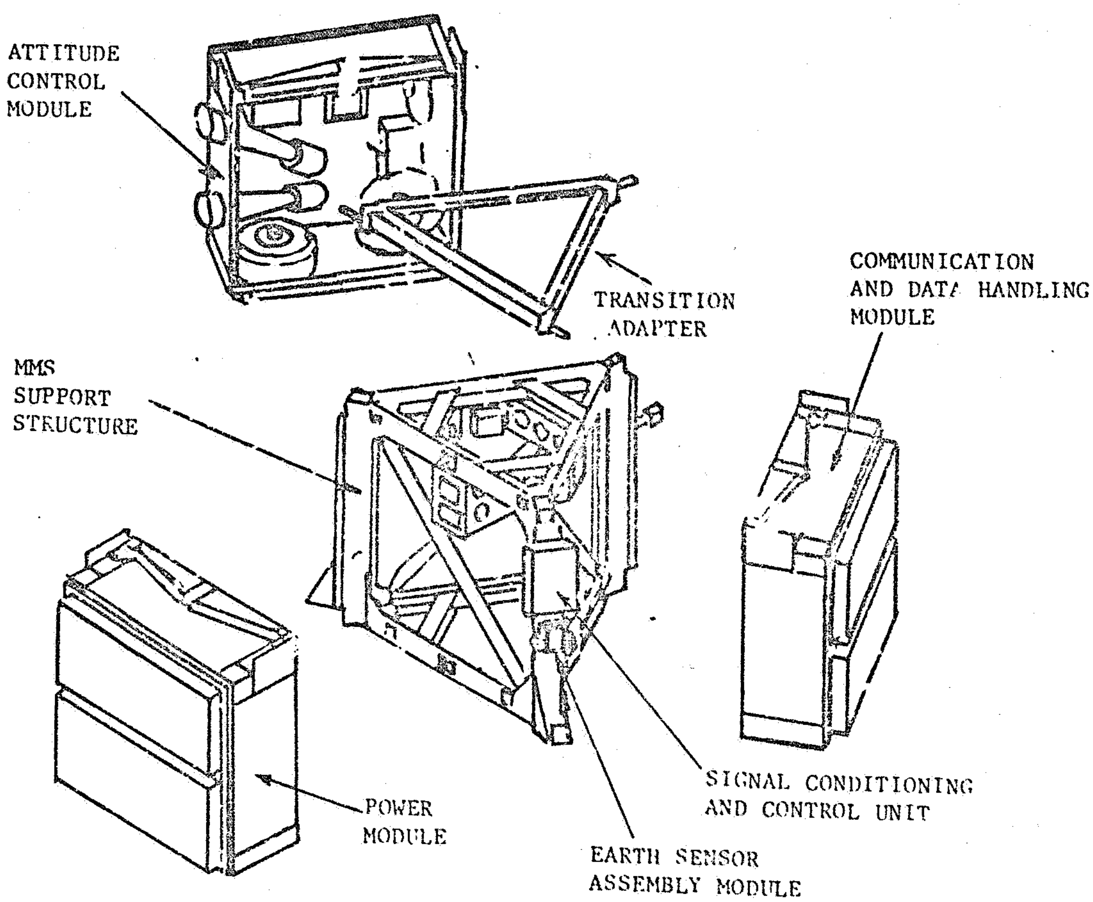

Figure 22.1-5. MMS Exploded View

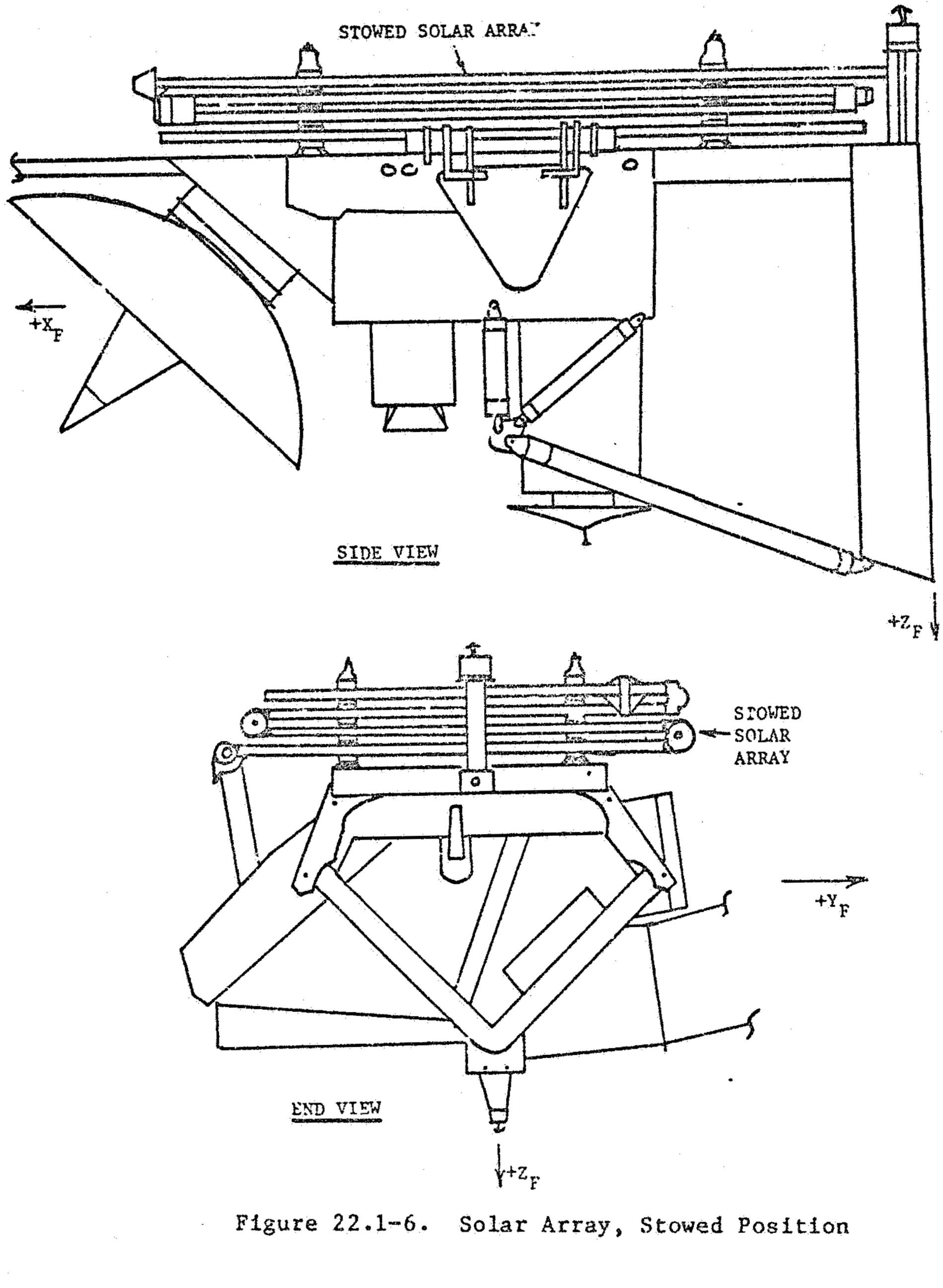

Figure 22.1-6. Solar Array, Stowed Position

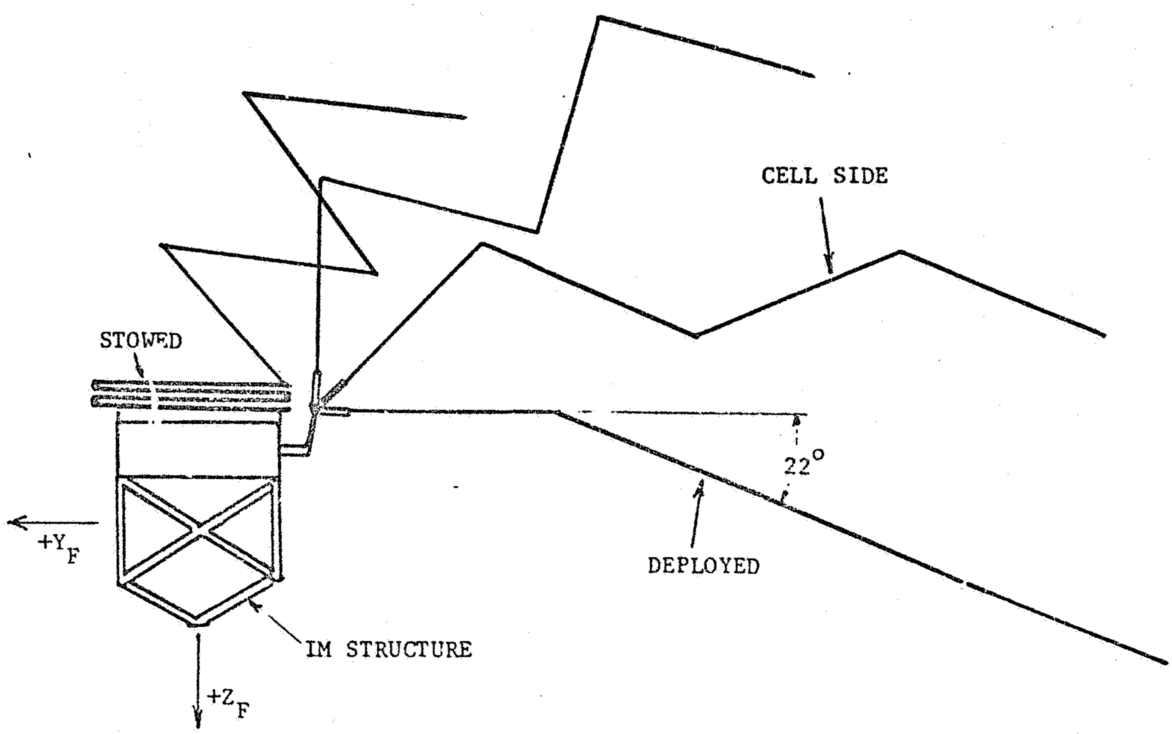

Figure 22.1-7. Solar Array, Deployment Stages

The fourth, and last, major structural element of the Flight Segment structure is the TDRSS antenna boom. The boom supports the electronics, drive mechanisms and high-gain antenna which is used to communicate with the TDRSS. It also provides a mounting surface for the GPS L-band antenna. The TDRSS antenna is stowed in the upper support structure during launch and is jettisoned prior to recovery by the Space Transportation System. It is shown in its deployed position in the general view of Figure 22-1; Figures 22.1-8 and 22.1-9 show it stowed and at several stages during deployment.

22.2 PERFORMANCE CAPABILITIES

22.2.1 FS COORDINATE AXES

The coordinate axes for the Flight Segment are designated X_F, Y_F, and Z_F. They are based upon a body fixed, right-hand Cartesian coordinate system, with the origin located at the intersection of X_F, Y_F, and Z_F. Specifically:

- The $+X_F$ axis is defined to be perpendicular to the IM/MMS interface plane, which is in turn defined by the interfacing surface of the IM Mission Adapter. The axis intersects the interface plane at the geometric center of the Mission Adapter interface bolt hole circle, with its positive sense directed through the Instrument Module from the FS coordinate system origin (defined by the intersection of the X_F axis and the Mission Adapter interface plane).

- The $+Y_F$ axis is defined to be parallel to the nominally defined axis of the solar array drive shaft, with positive sense outboard on the side opposite that of the deployed solar array.

- The $+Z_F$ axis is defined to be mutually orthogonal to the X_F and Y_F axes, with its positive sense defined so as to complete a right-hand Cartesian coordinate system with X_F and Y_F. The nominal orientation of $+Z_F$ is parallel to the optical axes of the MSS and TM payload instruments, with positive sense directed outboard in the same direction as the field of view of the TM and MSS.

Figure 22.2-1 shows the Flight Segment coordinate axes.

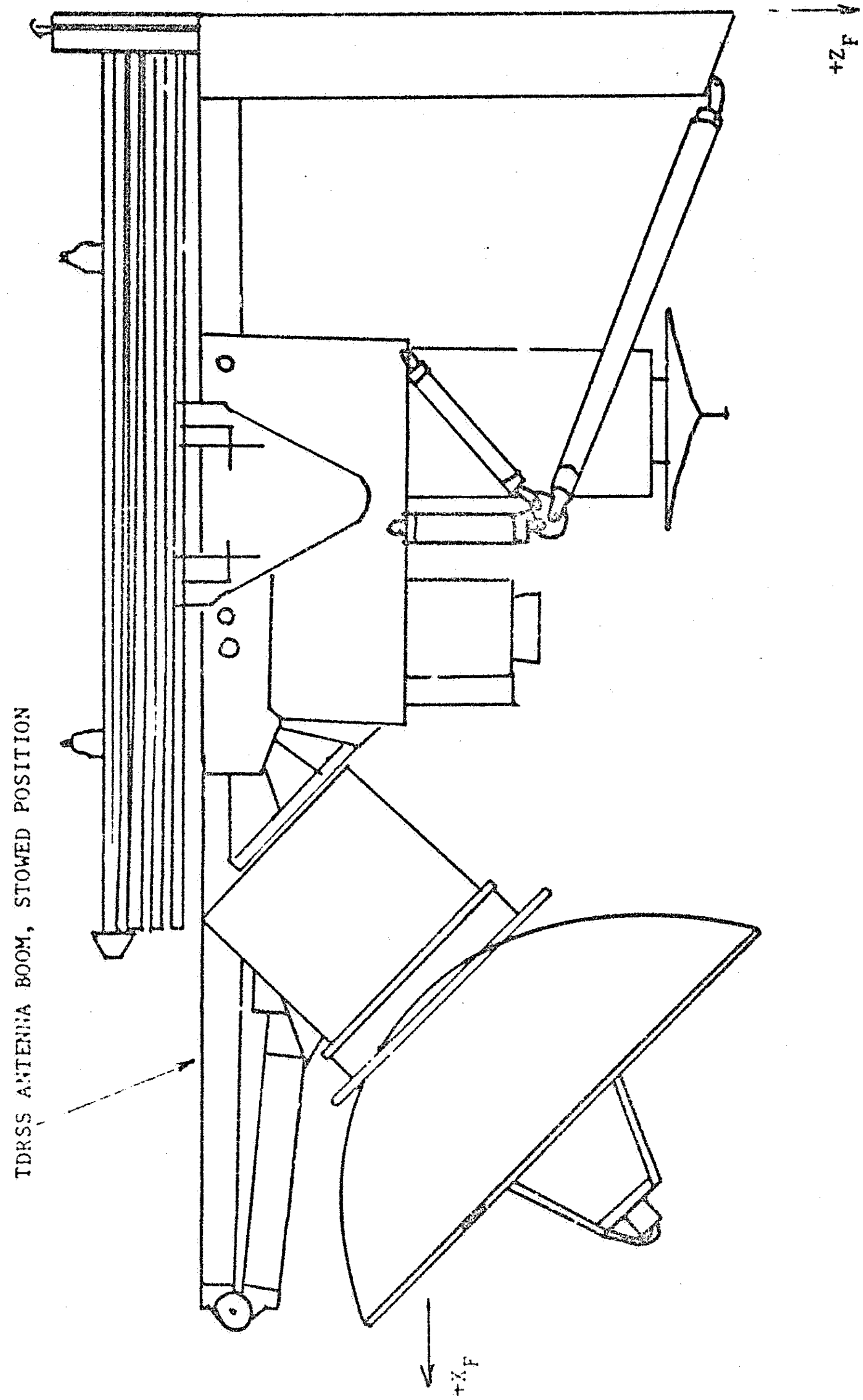

Figure 22.1-8. TDRSS Antenna Boom, Stowed Position

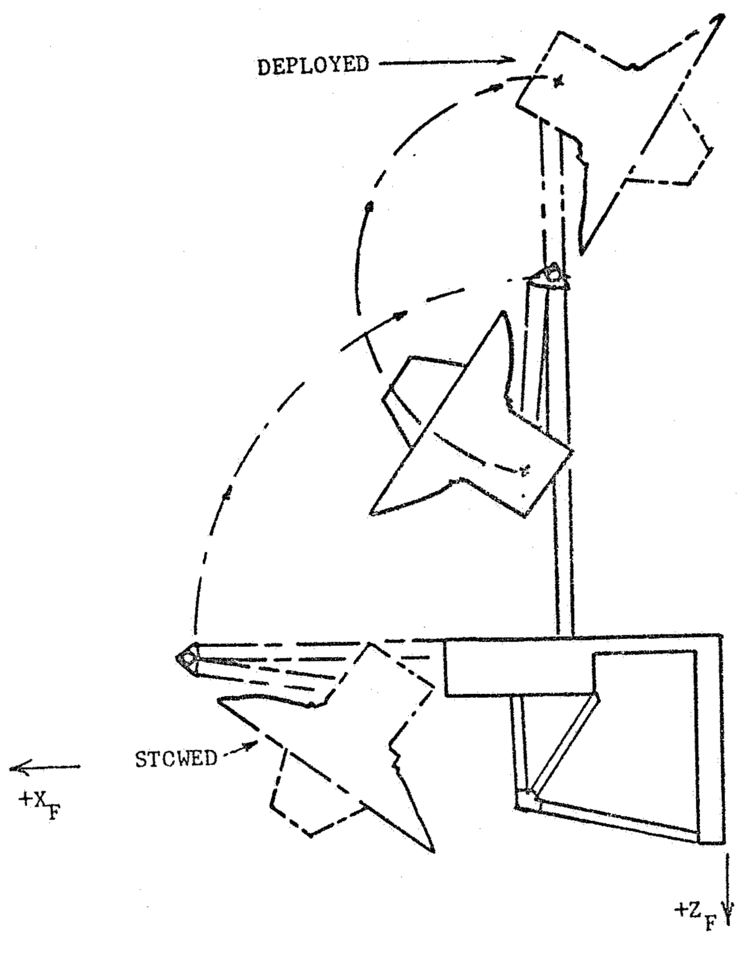

Figure 22.1-9. TDRSS Antenna Boom, Deployment Stages

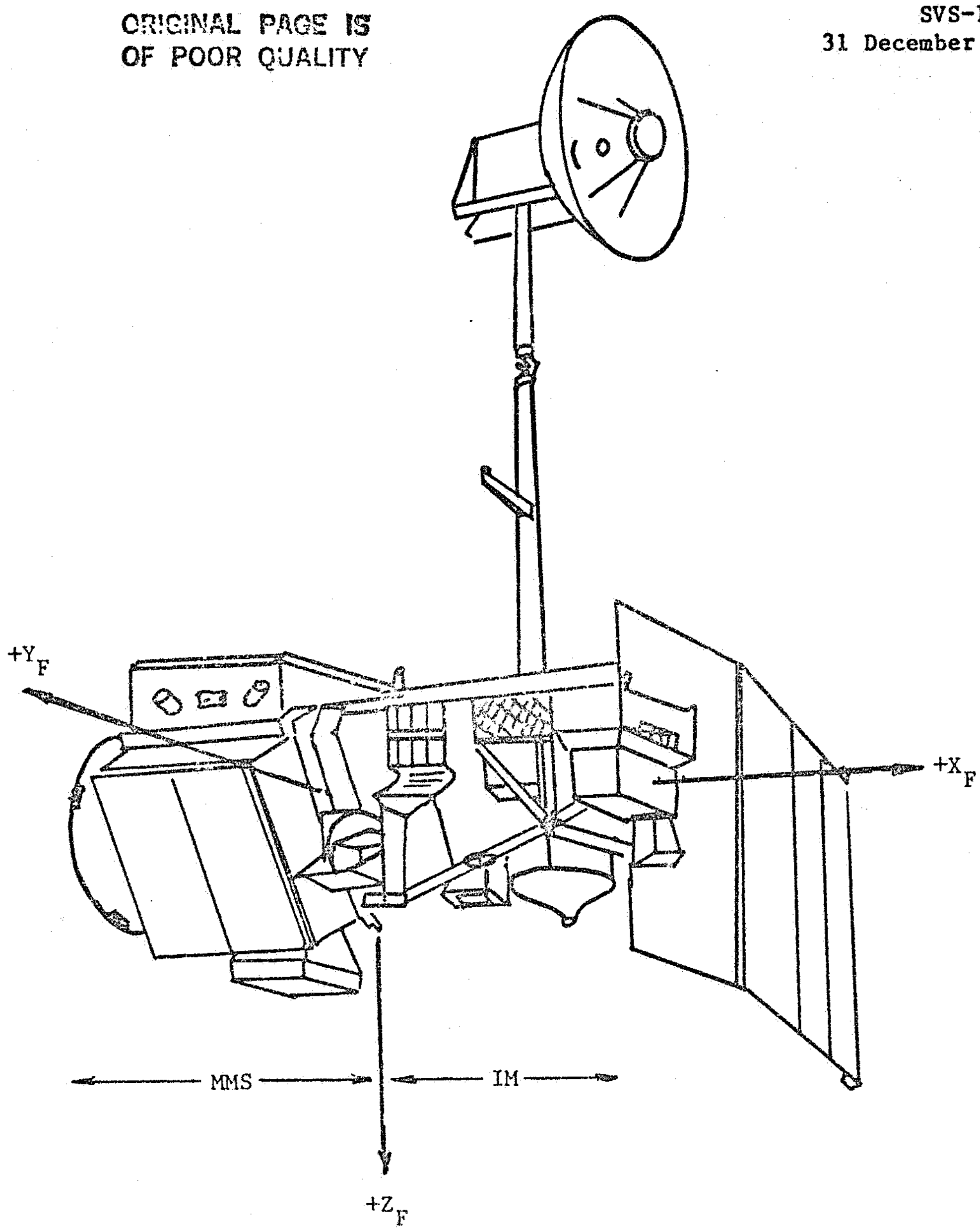

Figure 22.2-1. Flight Segment Coordinate Axes

MMS AXES

There is also a coordinate system which is referred to in documents pertaining to the MMS. This system, described here for information only, differs from that used for the overall flight segment. The three MMS coordinate axes--labeled X_M, Y_M, and Z_M to distinguish them from the FS axes--are defined as follows:

- The $+X_M$ axis is perpendicular to the IM/MMS interface plane, which is defined here as the interfacing surface of the Triangular Transition Adapter (TTA). The X_M axis intersects the interface plane at the geometric center of the TTA interface bolt hole circle. The positive sense of the X_M axis is directed through the MMS from the MMS coordinate system origin (defined as the intersection of the X_M axis with the Y_M, Z_M plane).

- The $+Y_M$ axis is nominally parallel to the axis of the horizontal trunion load pins of the TTA, with its positive sense as indicated in Figure 22.2-2.

- The $+Z_M$ axis is nominally coincident with the axis of the vertical load pin, also as shown in Figure 22.2-2.

The relative orientation of MMS coordinates to FS coordinates, for the completely assembled Flight Segment is illustrated in Figure 22.2-3. Note that X_F and X_M are nominally coincident, but oppositely directed (positive sense for each is outboard from the IM/MMS interface plane).

Equations for transforming the coordinates between MMS and FS systems are given in Table 22.2-1.

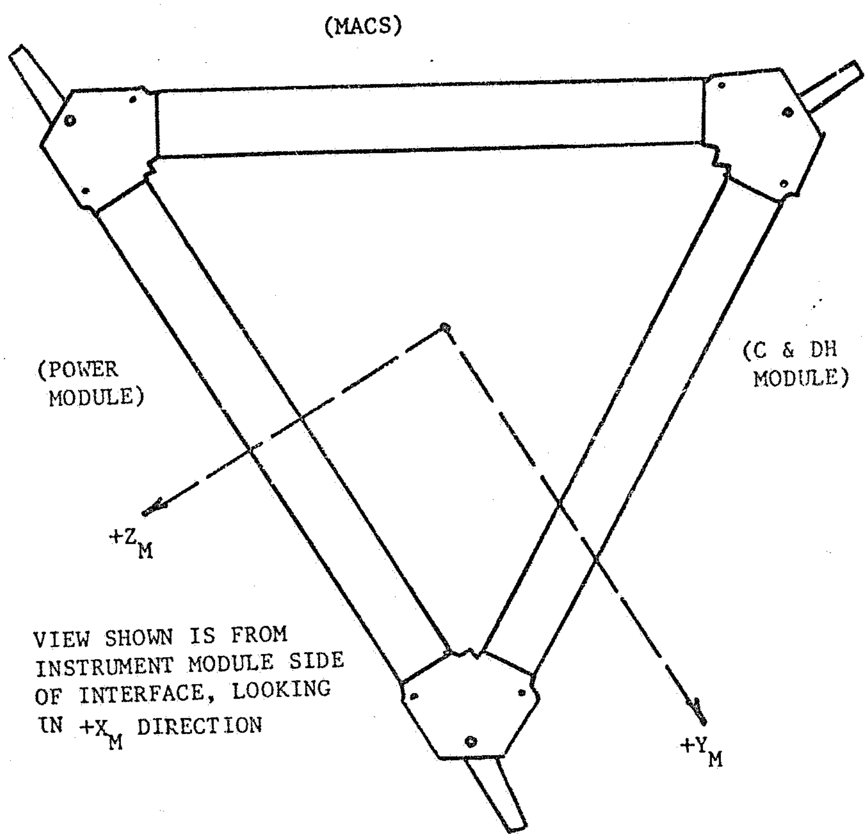

Figure 22.2-2. MMS Coordinates Relative to the TTA

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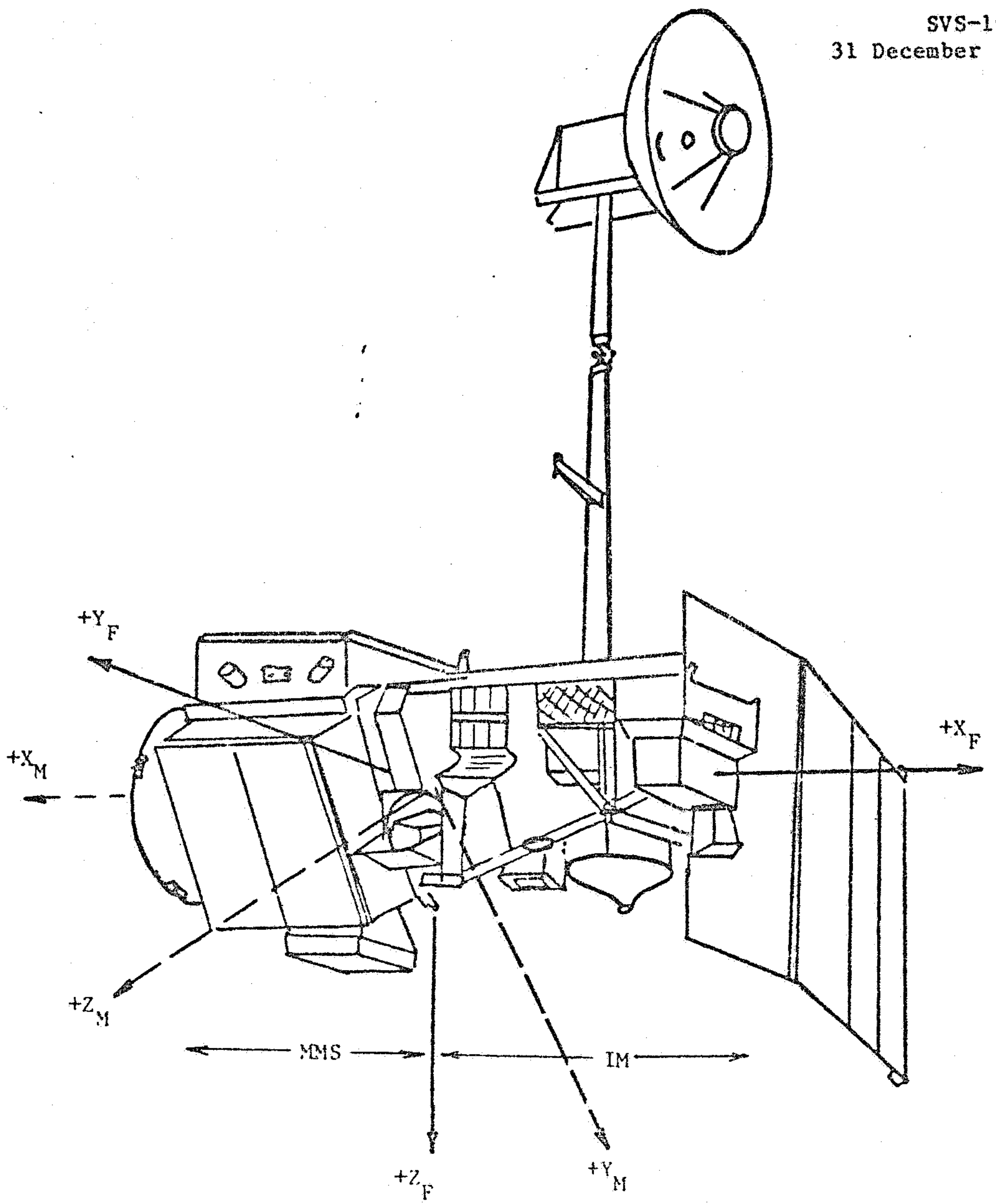

Figure 22.2-3. Coordinate System Relationships

Table 22.2-1. Coordinate Transformations

MMS to FS	FS to MMS
$X_F = 496.8 - X_M$	$X_M = 496.8 - X_F$
$Y_F = -0.5\ (Y_M - \ 3\ Z_M)$	$Y_M = -0.5\ (Y_F - \ Z_F)$
$Z_F = 0.5\ (\ 3\ Y_M + Z_M)$	$Z_M = 0.5\ (\ 3\ Y_F + Z_F)$

22.2.2 MATERIALS

A number of materials are used in the various structural elements of the Flight Segment. These materials are listed as follows:

Upper Support Structure (IM)	7075T7351 Aluminum
Truss Assembly (IM)	
- Tubes	Graphite-Epoxy CE-339/HMS
- Cluster fittings	7075T7351 Aluminum
Mission Adapter	
- Main structure	7075T7351 Aluminum
- Side plate stiffness	6061T6 Aluminum
Solar Array Substrate	
- Face sheets	2024T4 Aluminum
- Core	5052 Aluminum
TDRSS Antenna Boom	6061T6511 Aluminum
MMS Support Structure	7075T7351 Aluminum
TTA	
- Tubes	2024T2 Aluminum
- Fittings	7075T411 Aluminum

22.2.3 WEIGHTS

The total launch weight of the Landsat Flight Segment is 4424.24 lbs*. This weight is broken down as shown in the detailed weight statement of Table 22.2-2.

Total weight of the Flight Segment in the various operational configurations is shown in Table 22.2-3, Mass Properties.

22.2.4 MASS PROPERTIES

The Center of Mass (CM), moment of inertia about the CM, and products of inertia about the CM are given in Table 22.2-3. These properties are also given in Table 22.2-4 for various solar array orientations, for a full fuel load and for useable fuel expended.

22.2.5 ALIGNMENT

The mechanical alignment of the major IM subsystems is accomplished by reflectance tests from reference cubes. These tests will establish the absolute alignment of the subsystem relative to the reference axis of the Landsat-D. Tables 22.2-5 to 22.2-8 define the absolute and on-orbit knowledge alignment requirements of the several subsystems. The on-orbit knowledge is the uncertainty tolerance allowed on the axis of the subsystem which is defined by ground test measurements; i.e., the absolute alignment. Also shown on this series of tables are expected alignment errors (referred to as compliance). These predictions are based on development tests and analysis. Final confirmation of the major subsystem alignments will be obtained during Landsat-D system tests utilizing reference cubes.

22.2.6 SENSOR FIELDS-OF-VIEW

There are ten sensors mounted on the Landsat-D Flight Segment. These include the two primary instruments (Thematic Mapper and Multispectral Scanner) and eight other sensors as listed below. Each sensor has it own particular field-of-view; in some cases the FOV is a simple cone, others are more complex. The various sensors are listed below, with references to the figures which illustrate the fields-of-view.

- Thematic Mapper - FOV is basically a cone which is swept from side-to-side. See Figures 22.2-4 and 22.2-5.

- Multispectial Scanner - FOV is basically a cone which is swept from side to side. See Figures 22.2-4 and 22.2-5.

*As of December 1981 weight report.

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- 3 Coarse Sun Sensors, 2 mounted on the edges of the solar array, mounted on the Upper Support Structure. FOV of each sensor element is approximately 180 degrees; however, the sensors are operated in combination to provide the desired directional coverage. Note that the sensor elements are provided in pairs, with one element redundant. Figures 22.2-4, 22.2-5, and 22.2-6 show the location of the coarse sun sensors.

In normal operation, the two array-mounted sensors provide data for correcting the indexing of the solar array. As the solar array is indexed, the FOV of the sensors change relative to the spacecraft. The body-mounted sensor, located on the Upper Support Structure, was intended for use in a special mode of operation which is no longer used; the body-mounted sensor is therefore not used in normal operations.

- Fine sun Sensor - Refer to Figures 22.2-4, 22.2-7, 22.2-8. 22.2-9 and 22.2-10 for location and FOV details. Note that the basic FOV is 64 degrees square (±320).

- Earth Sensor - Mounted on MMS strut near SC & CU. Figure 22.2-11 shows the location. Note that there are two sensor elements. Figure 22.2-12 shows the Earth Sensor FOV.

- Star Trackers (2) - Conical field-of-view, each tracker. See Figure 22.2-7, 22.2-8 and 22.2-9.

- Bright Object Sensors (2) - 21 degrees basic field-of-view, each tracker. See Figure 22.2-7, 22.2-8 and 22.2-9.

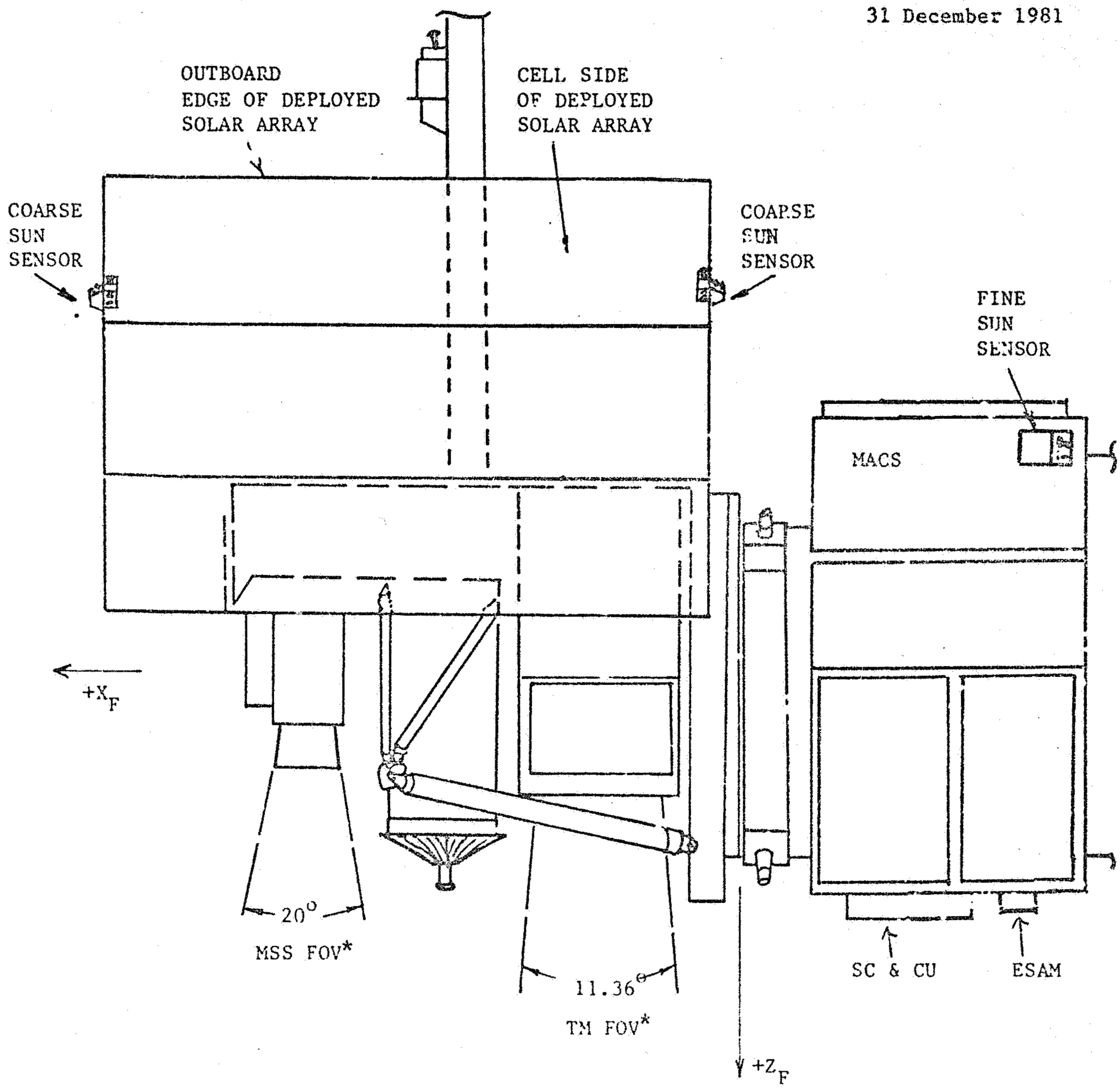


Figure 22.2-4. View Along $+Y_F$ Axis, Solar Array Side

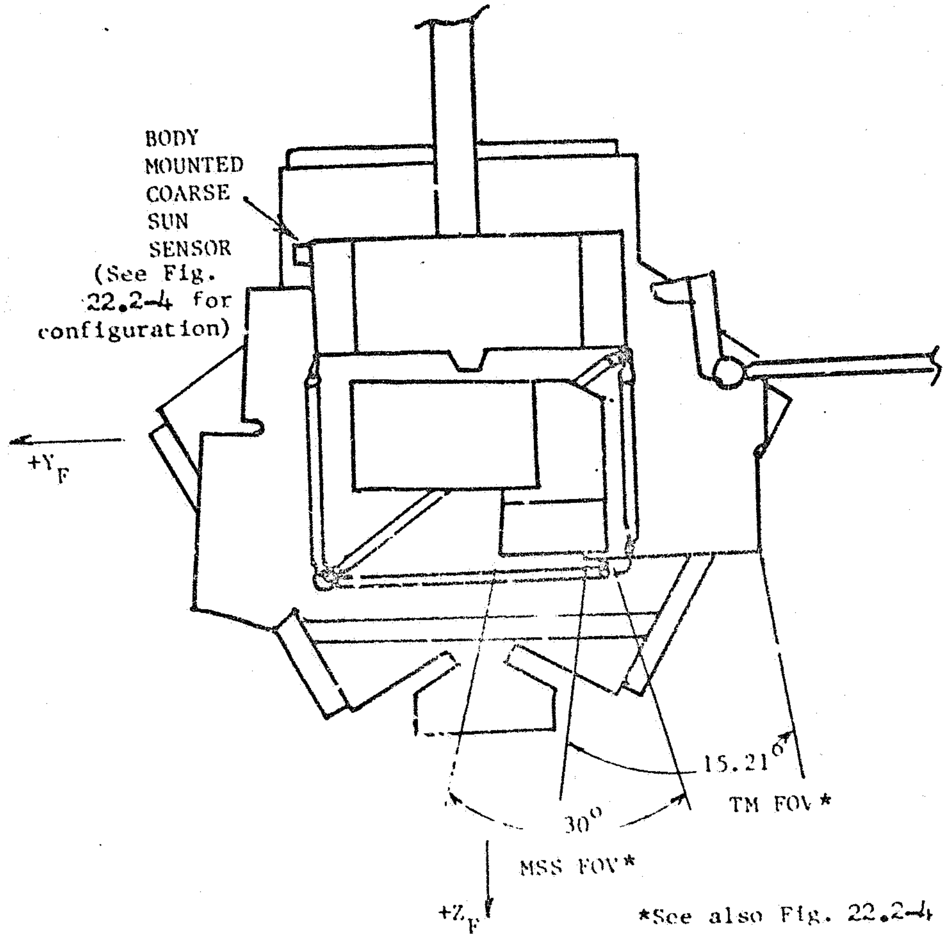


Figure 22.2-5. View Along $-X_F$ Axis, Facing End of IM

LSD-WPC-263

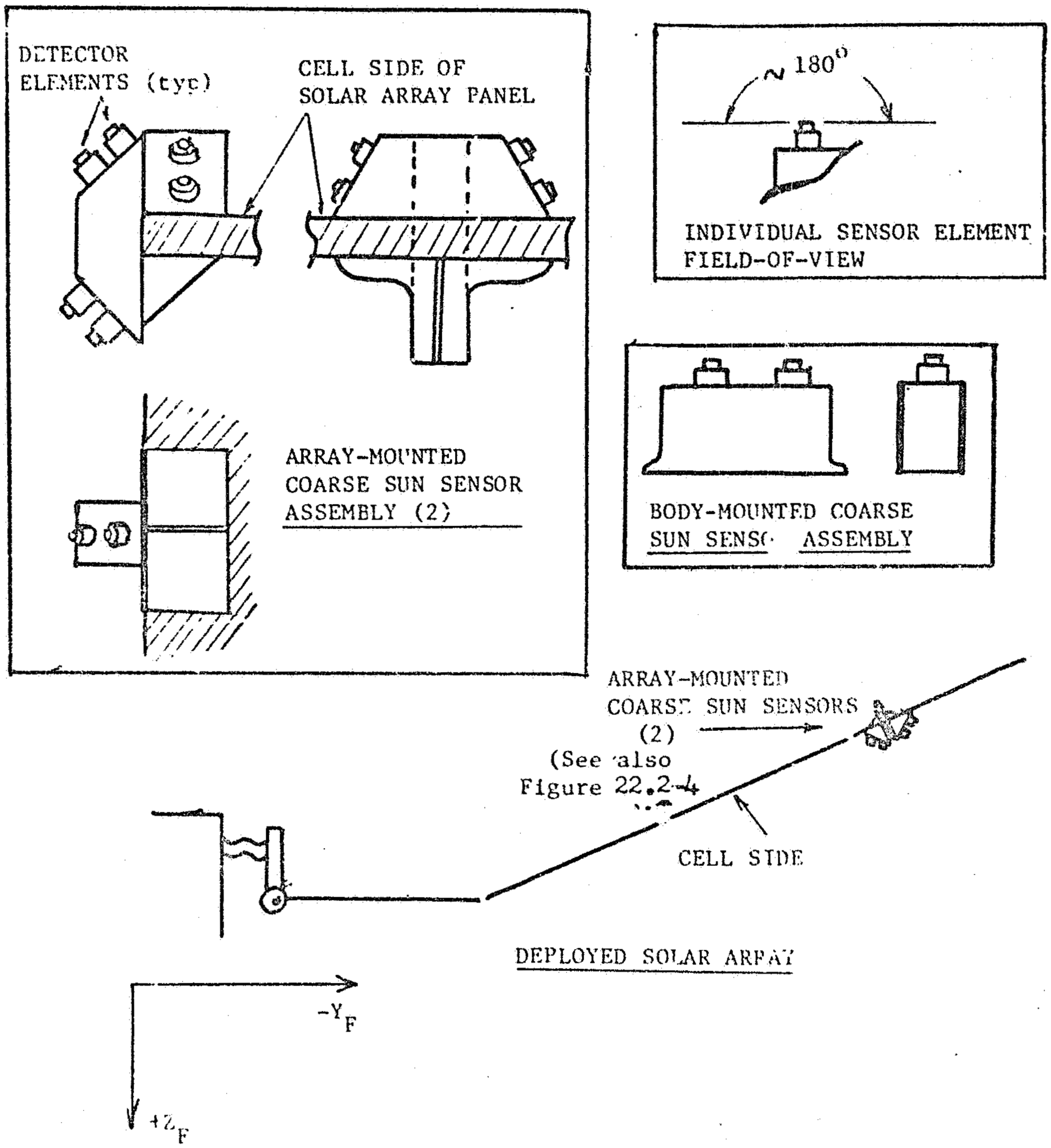
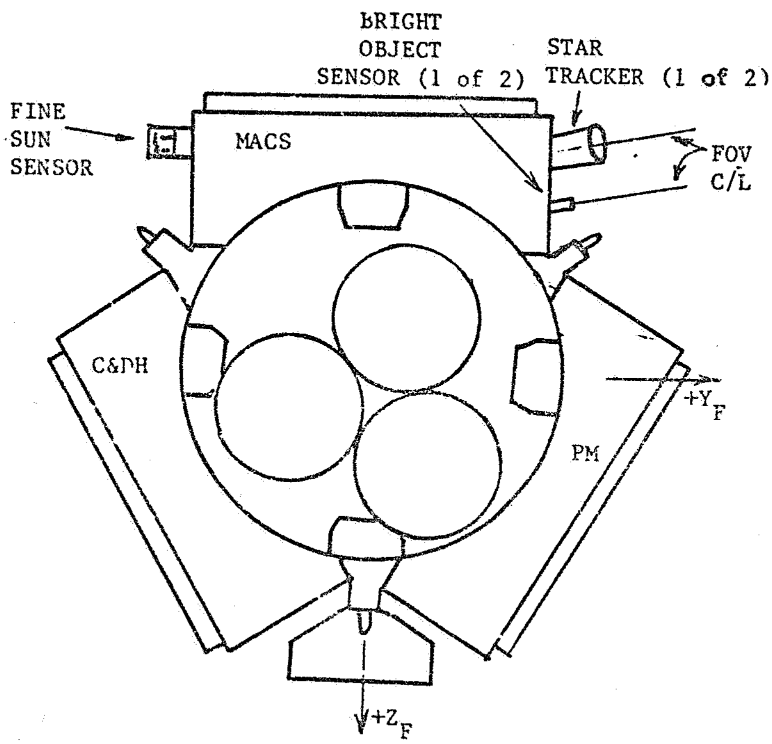


Figure 22.2-6. Coarse Sun Sensor Location and Field-of-View



(See Fig. 22.2-9 for a definition of the C/L angle relative to the spacecraft coordinates)

Figure 22.2-7. View Along $+X_F$ Axis, Facing Rocket Engine Module of MMS

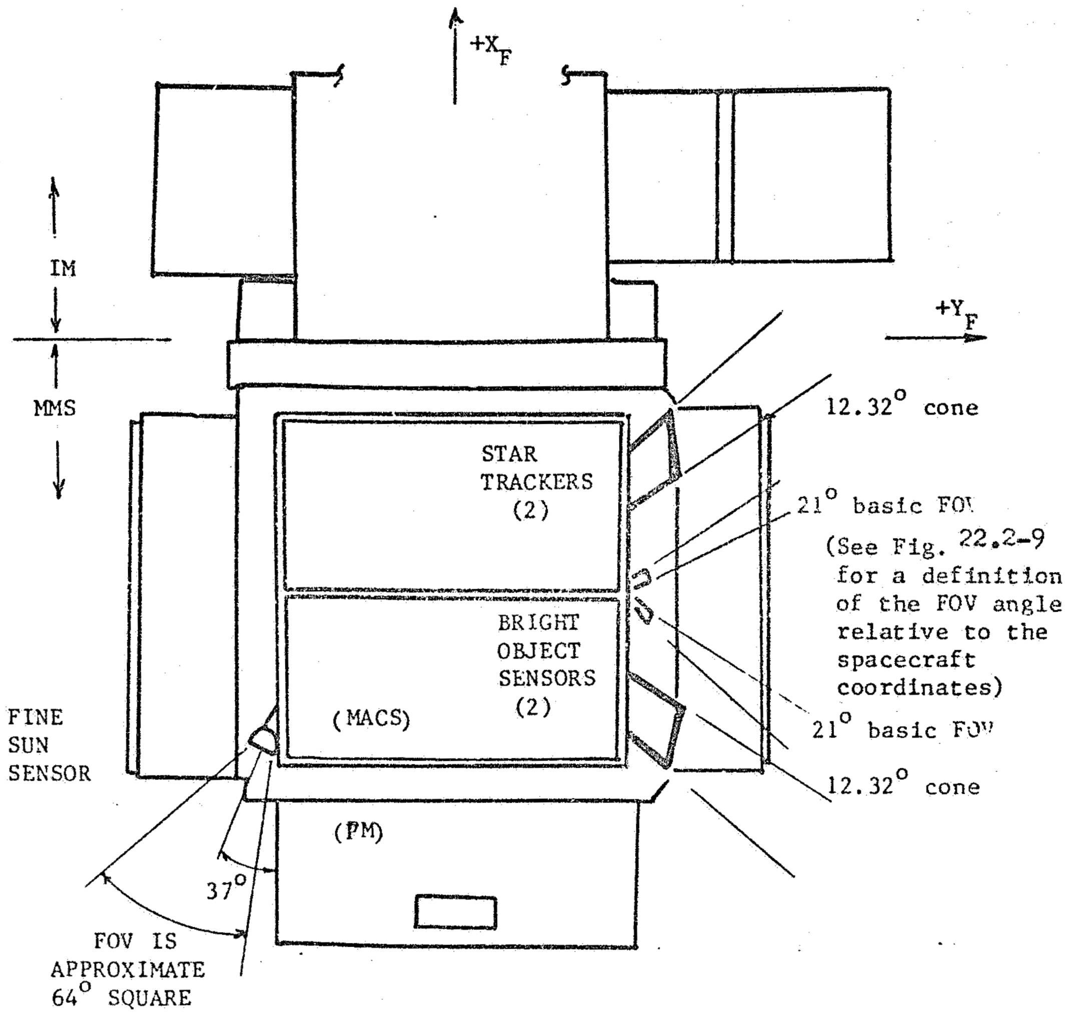


Figure 22.2-8. Top View, Looking Along $+Z_F$ Axis

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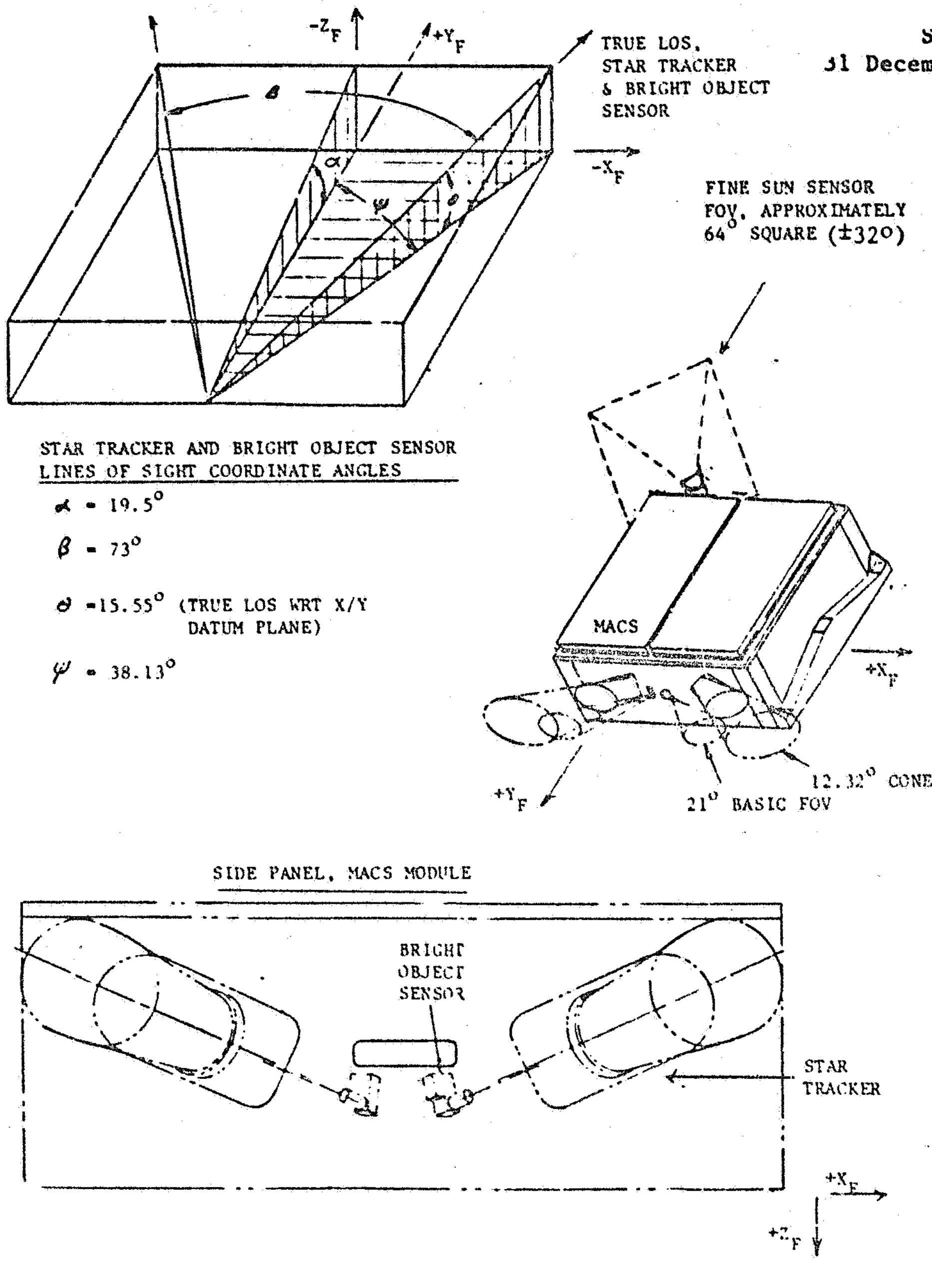

Figure 22.2-9. Fine Sun Sensor, Star Tracker, Bright Object Sensor

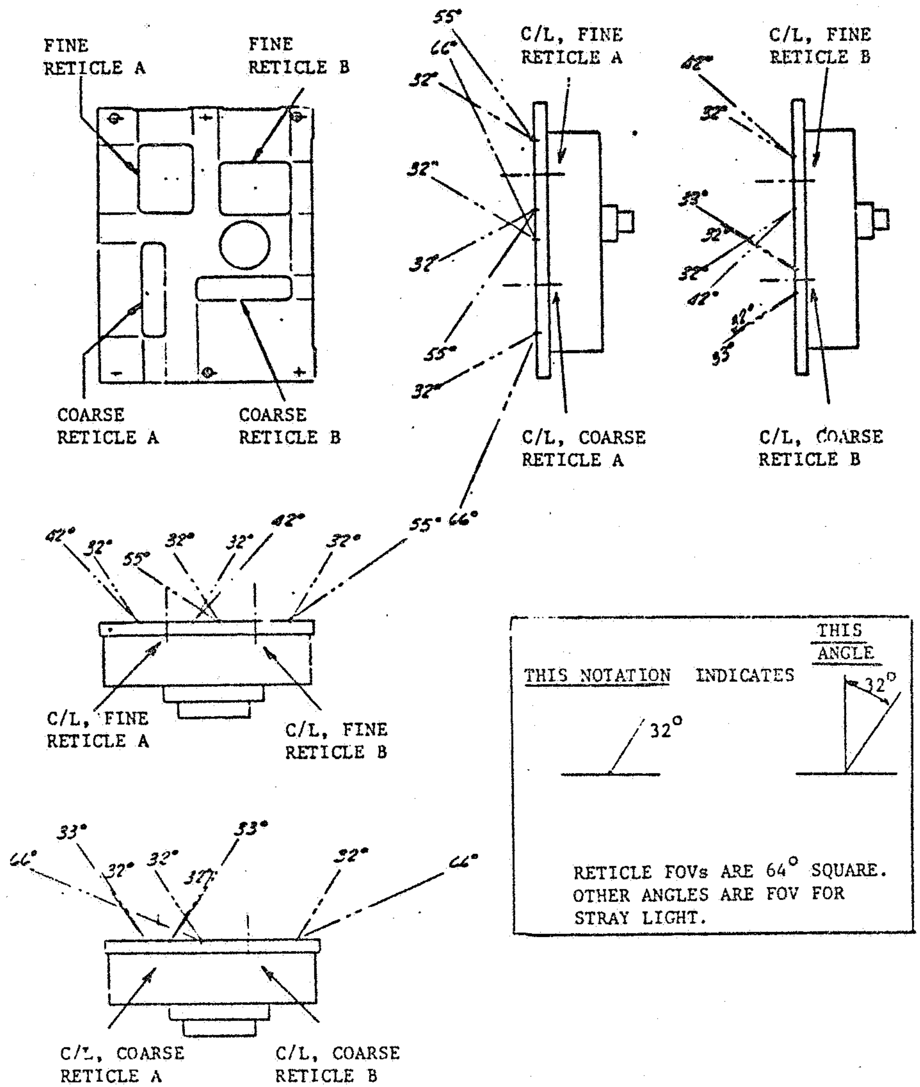

Figure 22.2-10. Fine Sun Sensor, FOV Details

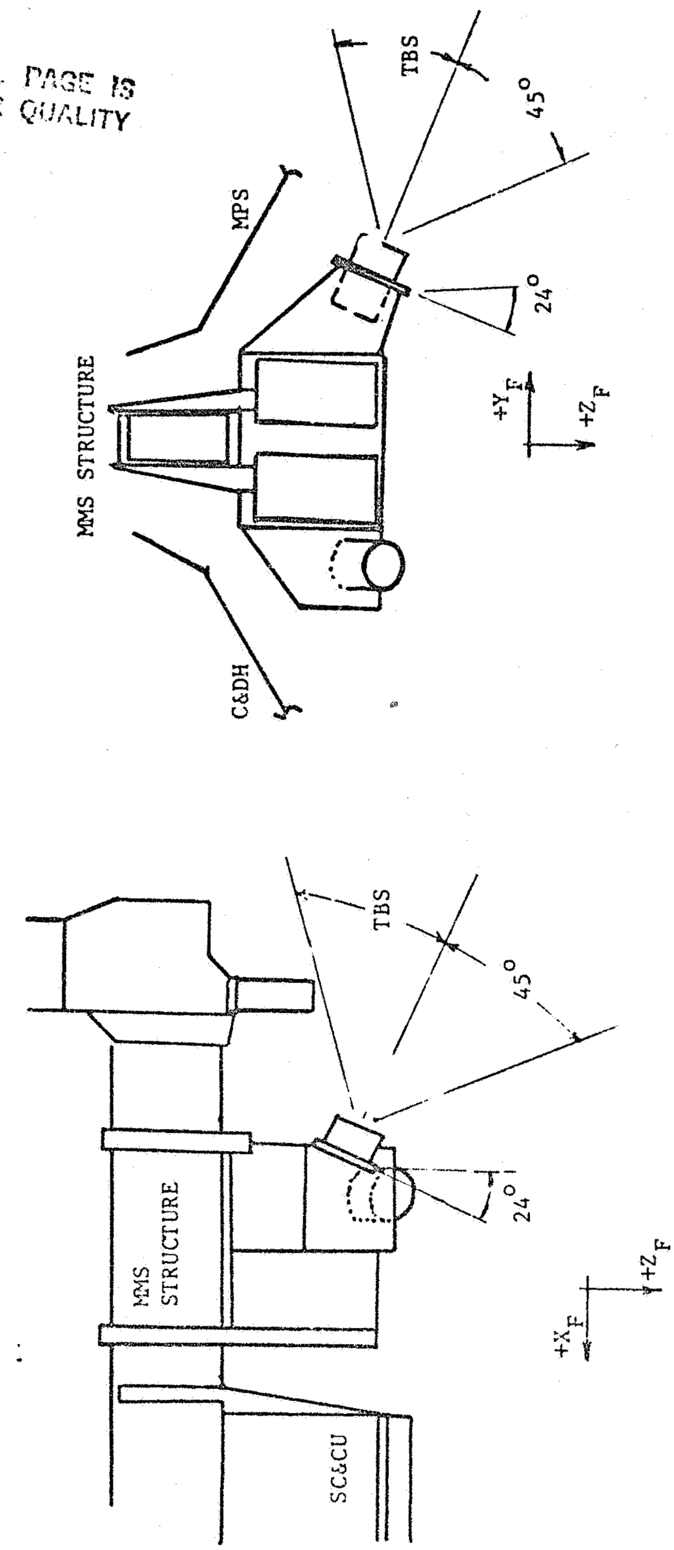

Figure 22.2-11. Earth Sensor Assembly Module Location

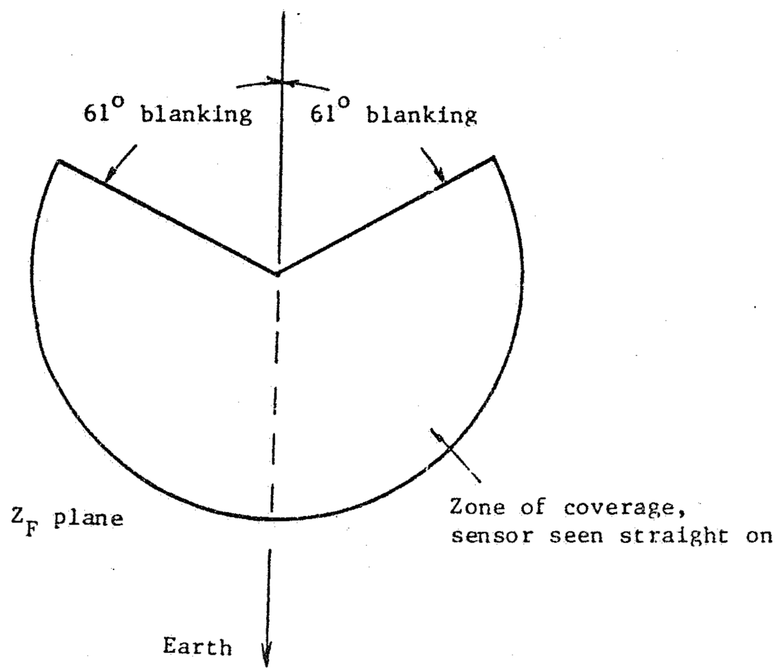

Figure 22.2-12. Earth Sensor FOV Details

Table 22.2-2. Detailed Weight Statement

ITEM	WEIGHT (LBS)
MULTI MISSION MOD S/C (DRY)	2056.77
SPACECRAFT (DRY) (NOTE 1)	1906.00
PAYLOAD ATTACH FITTING	150.77
PAYLOAD INSTRUMENTS	669.69
THEMATIC MAPPER	541.27
MULTISPECTRAL SCANNER	128.42
SCANNER	122.40
MULTIPLEXER	6.02
INSTRUMENT MODULE	1180.57
GLOBAL POSITIONING SYSTEM	54.89
L-BAND ANTENNA	2.36
RECEIVER PROCESSOR	44.90
PRE-AMPLIFIER	2.36
LOCAL OSCILLATOR	2.54
ANTENNA SUPPORTS	2.73
WIDEBAND MODULE	180.95
RF MODULE AND ANTENNA	176.78
TDRS ANTENNA BOOM	135.65
HINGES	26.07
MID BOOM HINGE	13.30
INBD BOOM HINGE	12.76
STOW MECHANISM	59.98
RF ADAPTERS	11.93
BOOM ADAPTERS	16.04
LATCH MECHANISM	23.21
LOCKOUT	8.80
JETTISON	11.58
DISCONNECT	1.20
BOOM SEGMENTS	33.54
MISC.	3.28

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Table 22.2-2. Detailed Weight Statement

ITEM	WEIGHT (LBS)
SOLAR ARRAY SYSTEM	168.49
SUBSTRATES	71.61
CELLS	39.19
RETENTION & DEPLOY SYS	31.70
RETENTION SYSTEM	8.38
HINGES	6.83
POWERED HINGE ASSY	12.03
SYNCHRONIZATION	4.45
DRIVE ASSEMBLY	14.70
YOKE (CRANK)	4.94
JETTISON ASSEMBLY & DISCONNECT	6.35
STRUCTURE	203.28
MISSION ADAPTER	60.89
UPPER STRUCTURE	93.52
LOWER TRUSS ASSY	20.07
OMNI ANTENNA SUPT	1.58
TDRS ANT. SUPT. BRKT	2.78
SOLAR ARRAY RETENSION FTGS	4.75
MSS SUPPORTS	10.64
PYRO MODULE SUPPORT	0.14
ADS MOUNT	0.50
PCD MOUNT	0.90
WIDEBAND MOUNT	1.90
MSS MUX SUPT.	1.35
MMS INTERFACE ITEMS	1.66
TM FILTER SUPPORTS	0.72
MISC ITEMS	4.39
ACTUAL WT. VARIATION	-2.49
THERMAL SUBSYSTEM	38.22
BLANKETS	24.86
IF MATERIAL	1.60
COATINGS	8.29
HEATERS & THERMOSTATS	2.47
MISC	1.00

Table 22.2-2. Detailed Weight Statement

ITEM	WEIGHT (LBS)
ELECTRICAL INTEGRATION	222.32
ELECTRONICS	85.64
REMOTE INTERFACE UNIT	28.22
EXPANDER UNITS	6.16
BUS COUPLING UNITS	1.02
POWER DISTRIBUTION UNIT	25.90
S-BAND TRANSMITTER	12.31
RF COMBINER	0.85
DIGITAL PROCESSOR UNIT	4.67
SUN SENSOR ASSY ON ARRAY	2.40
SUN SENSOR IN IM	0.14
ADS	3.30
CO-AX SWITCH	0.22
PYRO MODULE	0.45
ANTENNAS	1.98
OMNI S-BAND	0.71
SHAPED S-BAND	1.27
ELECTRICAL HARNESSES	134.70
INSTALLATION ITEMS	13.97
HARNESS SEGMENTS	120.73
FUEL & PRESSURANT	517.20
FUEL	514.00
PRESSURANT	3.20
TOTAL LAUNCH WEIGHT	4424.24

NOTE 1: INCLUDES ESAM, OSC, 3RD BATTERY, TAPE RECORDERS, AND THE PM1A MODULE.

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Table 22.2-3. Landsat-D Mass Properties

Operational Configuration	Weight (Lbs)	Center of Mass (Inches) (See Note 2) X	Y	Z	Moments of Inertia About CM (Slug-Ft2) IX	IY	IZ	Products of Inertia About CM (Slug-Ft2) PXY	PXZ	PYZ
Launch Mode	4396.	-6.4	2.4	-1.3	571.	2646.	2688.	-45.	-208.	14.
Separated	4245.	-4.0	2.4	-1.3	543.	2485.	2527.	-45.	-209.	16.
Array Deployed Antenna Stowed	4245.	-4.0	-2.6	-0.4	1328.	2478.	3319.	-295.	-163.	-28.
Array Deployed Antenna Deployed (See Note 2)	4245.	-7.9	-2.6	-9.0	2599.	3209.	2779.	-298.	-477.	-30.
Useable Fuel Expended (See Note 2)	3731.	-1.5	-3.0	-10.4	2582.	2909.	2491.	-272.	-416.	-33.
IM (Ref Only)	1822.	46.0	1.8	-5.9	180.	451.	463.	-25.	-50.	8.

NOTE 1: Array at 1200 hr position and antenna pointed in -X direction. Mass properties for other array and antenna positions are on Table 22-4.

NOTE 2: X=0 is Mission Adapter/Transition Adapter interface.

Table 22.2-4. Mass Properties for Various Array Orientations

FULL FUEL LOAD

ANG *	X	Y	Z	IX	IY	IZ	PXY	PXZ	PYZ	IX-IY **	IX-IZ **	IY-IZ **
0	-7.9	-2.7	-8.9	2554.	3162.	2775.	-302.	-479.	-31.	608.	221.	387.
15	-7.8	2.7	-8.9	2555.	3175.	2787.	-329.	-481.	-28.	620.	232.	387.
30	7.7	-2.7	-9.0	2556	3187.	2798.	-354	485.	-17.	631.	243.	388.
45	7.6	-2.7	-9.0	2557.	3197.	2807.	-376.	-489.	-1.	640.	250.	390.
60	-7.5	-2.7	-9.1	2558.	3205.	2814.	-392.	-494.	21.	647.	256.	391.
75	7.5	2.7	-9.2	2560.	3211.	2818.	-403.	-500.	46.	651.	259.	393.
90	-7.5	-2.7	-9.3	2561	3214.	2820.	-407.	-505	73.	653.	259.	394.
105	7.5	-2.7	-9.5	2562.	3213.	2818.	-403.	-511.	100.	651.	256.	395.
120	-7.5	-2.7	-9.6	2563.	3209.	2814.	-393.	-516.	126.	647.	251.	395.
135	-7.6	-2.7	-9.7	2563.	3203.	2807.	-376.	-520.	147.	640.	244.	396.
150	-7.7	-2.7	-9.7	2563.	3193.	2798.	354.	-524.	164.	631.	235.	396.
165	-7.8	-2.7	-9.8	2563	3182.	2787	-329.	-526.	175.	619.	224.	396.
180	-7.9	-2.7	-9.8	2563.	3170.	2775.	-302.	-527.	178.	607.	212.	396.
195	8.0	-2.7	-9.8	2563.	3158	2762.	-275	-526.	175.	595.	199.	396.
210	-8.1	-2.7	-9.7	2563.	3146.	2750.	-249.	-524.	164.	583.	187.	396.
225	-8.2	-2.7	-9.7	2563.	3135.	2740.	-228.	-519.	148.	573.	177.	396.
240	-8.3	-2.7	-9.6	2563.	3127.	2732.	-211.	-514.	126.	565.	169.	395.
255	8.3	-2.7	-9.5	2562.	3121.	2727.	-201.	-508.	101.	559.	165.	395.
270	-8.3	-2.7	-9.3	2561.	3119.	2725.	-197.	501.	74.	558.	164.	394.
285	-8.3	-2.7	-9.2	2560.	3119.	2727.	-200.	-494	46.	560.	167.	393.
300	8.3	2.7	-9.1	2558.	3123.	2732.	-211.	-488.	21.	565.	174.	391.
315	-8.2	-2.7	-9.0	2557.	3130	2740.	-228.	-483.	-1.	573.	183.	390.
330	-8.1	-2.7	-9.0	2556.	3139.	2751.	-249.	-480.	-17.	583.	195.	388.
345	8.0	-2.7	-8.9	2555.	3150.	2763.	-274.	-479	-28.	595.	208.	387.
					AVERAGE VALUES		-302.	-503.	73.			

(SEE ALSO NEXT PAGE - USEABLE FUEL EXPENDED)

* Ang = Array position in degrees. Zero is 1200 hrs.

** $I_X - I_Y$, $I_X - I_Z$, $I_Y - I_Z$ = Absolute value of inertia difference ($SL\text{-}FT^2$)

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Table 2.2-4. Mass Properties for Various Array Orientations (Cont'd)

USEABLE FUEL EXPENDED

ANG	X	Y	Z	IX	IY	IZ	PXY	PXZ	PYZ	IX-IY	IX-IZ	IY-IZ
0	1.5	-3.1	-10.2	2537	2863.	2487.	-275.	-419.	-35.	325.	50.	376
15	1.4	-3.1	-10.2	2538.	2874.	2498.	-302.	-421.	-31.	336	40.	376.
30	1.2	-3.1	-10.3	2533	2884.	2507	-323	-424.	-21.	340.	31.	377.
45	1.1	3.1	-10.4	2540.	2893.	2516.	-349.	-428	-4.	354.	24.	378.
60	1.1	3.1	-10.5	2541.	2901.	2522	-366.	-432.	18.	360.	19.	379.
75	1.0	3.1	-10.6	2542	2906.	2525	-376.	-437.	43.	364.	17.	380.
90	1.0	3.1	-10.7	2543	2908	2527.	-380.	-442	70.	365.	16.	381.
105	1.0	3.1	10.3	2544.	2907.	2525.	-377.	-447.	97.	363.	18.	382.
120	1.1	3.1	-11.0	2544.	2903.	2521.	-366.	-451.	122.	360.	22.	382.
135	1.1	3.1	-11.1	2544	2897.	2515.	-350	-455.	144.	354.	29.	382.
150	1.3	3.1	-11.2	2544.	2889.	2507.	-328.	-458.	161.	345.	37.	382.
165	1.4	-3.1	-11.2	2544.	2879	2497.	-303	-460.	171.	336.	46.	382.
180	-1.5	-3.1	11.2	2543.	2868.	2487.	-276.	-461.	175.	325.	57.	382.
195	-1.6	3.1	11.2	2544.	2857	2475.	-248.	-461	171	314.	68.	382.
210	1.8	3.1	-11.2	2544.	2847	2465.	-223.	-459	161.	303.	79.	382.
225	1.9	-3.1	-11.1	2544.	2838.	2456.	-201.	-455.	144.	294.	88.	382.
240	1.9	-3.1	-11.0	2544.	2830.	2448.	-185.	-450	123.	286.	96.	382.
255	2.0	-3.1	10.9	2544.	2825.	2444.	-174.	-445.	97.	282.	100.	382.
270	2.0	-3.1	-10.7	2543.	2823.	2442.	-171.	-438.	70.	280.	101.	381.
285	2.0	-3.1	-10.6	2542	2824.	2444.	-174.	-432.	43.	282.	98.	380.
300	1.9	-3.1	-10.5	2541.	2827.	2448.	-185.	-427.	18.	287.	92.	379.
315	1.9	-3.1	-10.4	2540.	2834.	2456.	-201.	-423.	-4.	294.	84.	378.
330	-1.7	3.1	-10.3	2538.	2842.	2465.	-223.	-420.	21.	303.	73.	377.
345	-1.6	-3.1	-10.2	2538.	2852.	2476	-248.	-419.	-31.	314.	62.	376.
					AVERAGE VALUES		-275.	-440.	70.			

Ang = Array position in degrees. Zero degree is 1200 hours.

$I_X - I_Y$, $I_X - I_Z$, $I_Y - I_Z$ = Absolute value of inertia difference ($SL\text{-}FT^2$)

Table 22.2-5. TM Alignment (TM Optical Axis to MACS Reference Cube (MRC))

		Error (Arc-Second) Absolute	On-Orbit Knowledge
Requirement	$Theta_X$	3600	360
	$Theta_Y$	3600	756
	$Theta_Z$	3600	756
Compliance (RSS of 3-sigma Errors)	$Theta_X$	900	380
	$Theta_Y$	900	363
	$Theta_Z$	900	389

Absolute Error - Meet Requirements

On-Orbit Knowledge may require On-Orbit Calibration to meet X.

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Table 22.2-6. MSS Alignment (Mss Optical Axis to TM Optical Axis)

		Error (Arc-Second) Absolute	On-Orbit Knowledge
Requirement	$Theta_X$	540	432
	$Theta_Y$	1800	504
	$Theta_Z$	1800	504
Compliance (RSS of 3-sigma Errors)	$Theta_X$	510	334
	$Theta_Y$	540	360
	$Theta_Z$	720	492

Shimming will be used to meet absolute requirement

On-Orbit knowledge meets requirement without On-Orbit calibration

Table 22.2-7. ESAM Alignment (ESAM Cube to MRC)

		Error (Arc-Seconds)	
		Absolute	On-Orbit Knowledge
Requirement	$Theta_X$	3600	360
	$Theta_Y$	3600	360
	$Theta_Z$	3600	360
Compliance (RSS of 3-sigma Errors)	$Theta_X$	1200	236
	$Theta_Y$	900	274
	$Theta_Z$	900	274

Absolute and On-Orbit knowledge meets requirements

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Table 22.2-8. ADSA Alignment (ADSA Cube to TM Cube)

		Error (Arc-Seconds) On-Orbit Knowledge
Requirement	$Theta_X$	412
	$Theta_Y$	412
	$Theta_Z$	412
Compliance (RSS of 3-sigma Errors)	$Theta_X$	172
	$Theta_Y$	174
	$Theta_Z$	172

On-Orbit knowledge meets requirements

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